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RESEARCH MEMORANDUM

for the

Civil Aeronautics Administration

FLYING QUALITIES OF A HIGH-PERFORMANCE

PERSONAL-OWNER AIRPLANE

By James J. Adams and James B. Whitten

Langley Aeronautical Laboratory
Langley Field, Va.

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**NATIONAL ADVISORY COMMITTEE
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WASHINGTON**

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SUMMARY

An investigation has been conducted at the Langley Laboratory to measure the flying qualities of a high-performance personal-owner airplane to investigate the possible causes of instrument flying accidents with aircraft of this general type.

The results of the investigation show that the test airplane satisfactorily meets most present-day flying qualities requirements. It was found, however, that the lateral oscillations were marginally damped and that there was no aerodynamic warning prior to the stall, which is characterized by a rapid roll-off.

The airplane was subject to continuous lateral oscillations in rough air, and these lateral oscillations continually excited the rate-of-turn indicator. Since the pilot depends on the rate-of-turn indicator to show changes in airplane attitude when there is no directional gyro or artificial horizon, this characteristic made instrument flying more difficult. Other factors, which might affect the instrument flying qualities, are the rapid spiral divergence at low speed and the ease with which the airplane can exceed its maximum allowable airspeed in relatively gradual dives.

It was found that, during simulated instrument conditions, recoveries from unusual attitudes could be made with little control movement, and without the airplane exceeding its airspeed and acceleration limits.

The lack of aerodynamic stall warning and the rapid roll-off at the stall could contribute to stall-spin accidents with high-performance personal-owner aircraft. In a take-off, accidents could be caused by the fact that the airplane could be pitched to an angle of attack beyond the stall where sufficient power to climb was not available.

INTRODUCTION

The National Advisory Committee for Aeronautics has, in the past, measured the handling qualities of several personal-owner airplanes (reference 1). By present standards these airplanes were of relatively low power and low wing loading; therefore it was considered desirable to investigate the characteristics of a high-performance personal-owner airplane such as are being produced at the present time. In addition, the CAA requested an investigation to determine possible causes of a number of accidents in high-performance personal-owner airplanes. The accidents that are of chief concern are those that are caused by structural failure of the airplane in the air during instrument flying condition. In several accidents of this type, airplanes have been observed to dive out of clouds and to lose their wings in an attempt to regain a safe attitude. Also of concern are the stall-spin type of accidents.

In the present investigation the flying qualities of a Beech B-35 Bonanza airplane, selected as an example of a modern high-performance personal-owner airplane, were measured and are presented in this paper. This investigation includes tests to determine the longitudinal and lateral stability and control, stalling characteristics, spiral divergence characteristics, the ability to recover from unusual attitudes while flying under a hood and the speed increase in steady dives.

DESCRIPTION OF AIRPLANE

The Beech B-35 Bonanza is a four-place, low wing, high-performance personal-owner airplane equipped with a Continental E-185-1 engine and a Beech electric constant speed propeller. The airplane also has landing flaps and retractable tricycle landing gear. Stall strips are located on the leading edge of the inboard section of each wing. Photographs of the airplane are presented in figure 1, and a three-view drawing with over-all dimensions is shown in figure 2. Physical characteristics and the allowable center-of-gravity limits of the airplane are listed in table 1.

The airplane has a V-tail with 30° dihedral. Elevator control is obtained by moving the control surfaces symmetrically; rudder control, by moving the control surfaces asymmetrically. Elevator and rudder control are obtained simultaneously by means of a differential mechanism located between the control surfaces and the control wheel and rudder pedals. Figure 3(a) shows the variation of the control-surface position with control-wheel position and rudder-pedal position. The solid lines denote the range of deflections within the stops on the control wheel and rudder pedals and within the stops on the flaps themselves. The

dotted lines in each corner of the plot represent the deflection to which the flap that is not at its maximum deflection could be forced by stretching the control cables. Throughout this paper the elevator angles and rudder angles given are in accord with the following formula:

$$\text{Elevator angle, } \delta_e = \frac{1}{2} (\text{Right control surface angle} + \text{Left control surface angle})$$

$$\text{Rudder angle, } \delta_r = \frac{1}{2} (\text{Left control surface angle} - \text{Right control surface angle})$$

A plot of the variation of aileron angle with control-wheel angle is shown in figure 3(b).

The friction and spring forces of the control systems are presented in figure 4. The aileron and rudder-control systems are connected by a spring, which hereafter is referred to as a coordinating spring. Figure 4(a) shows the variation of force that is required to deflect each of these controls when the other is held fixed at the cockpit controls. The elevator-control system incorporates a centering spring, and the neutral position of this centering spring adjusts with the elevator trim tab. Figure 4(b) shows the force variation that is required to deflect the elevator at a particular trim tab setting, and the variation of the neutral position of the elevator with trim tab position.

The airplane has no rudder trim device. The ailerons were equipped with fixed bent tabs on each aileron.

Longitudinal stability tests were run at three different center-of-gravity positions. The forward position was obtained by placing 100 pounds of lead ballast on the engine mounting brackets. The rearward position was obtained by putting 50 pounds of lead ballast in the baggage compartment and 20 pounds in the extreme tail. The two wing gas tanks were loaded equally at the beginning of each flight except for the flight in which the airplane was loaded asymmetrically. During the flights, gasoline was drawn from the left tank initially. During long flights an attempt was made to keep the gas load balanced to within 5 gallons. For the asymmetrically loaded case the left tank was filled and the right tank was left empty; also the pilot occupied the left seat and right seat was left empty. The weight of the airplane during the tests varied between 2450 pounds and the maximum allowable weight of 2650 pounds, depending on the amount of ballast and the number of instruments carried.

All flights were made at an altitude of between 3000 and 5000 feet.

INSTRUMENTATION

The quantities measured during the tests were airspeed, normal acceleration, control position, control force, sideslip angle, rolling velocity, yawing velocity, and pitching velocity. During the tests of the stalls, spiral divergence, and blind flying recoveries, the airplane attitude angles, roll angle, yaw angle, and pitch angle were measured by measuring the gimbal angles of gyro instruments. No attempt has been made to correct these gimbal angles to true attitude angles, but the recorded angles serve to measure qualitatively the attitude angles.

The airspeed was measured with a swivel head static tube and a shielded total-pressure tube mounted 1 chord ahead of the right wing tip. The recorded airspeed was corrected by applying a typical position error to the static pressure. The sideslip angle was measured with a flow-direction vane mounted 1 chord ahead of the left wing tip. No correction for outflow has been made to the recorded sideslip angle. All measurements were made and recorded with standard NACA instruments. In the time histories presented in the paper, which are reproductions of the actual film records, some of the instruments use more than one mirror or trace to cover the range of values of the quantity being measured. The instruments and batteries were mounted in the area ordinarily occupied by the rear seat and baggage compartment. The pick-ups for the elevator and rudder angles were located at the control differential mechanism in such a manner that the elevator and rudder angles were recorded as defined in DESCRIPTION OF AIRPLANE. The aileron angle was measured at the aileron hinge.

RESULTS AND DISCUSSION

The discussion of the handling qualities of the Beech B-35 Bonanza airplane presented in this paper is based on the criterions established in references 2 and 3. These requirements are used as a guide where they are applicable since they have been established through experience with a large number of airplanes. Additional tests which are not covered by these requirements but which are concerned with particular problems of high performance airplanes during instrument flying conditions were also made during the investigation. These additional tests are the spiral divergence tests, the blind flying recoveries, and the speed increase tests.

HANDLING QUALITIES

Longitudinal Stability and Control

Dynamic longitudinal stability.- The dynamic longitudinal stability of the airplane was tested by abruptly moving and then releasing the elevator control when the airplane was trimmed at 180 miles per hour in the power on, clean condition. A time history of this maneuver is presented in figure 5. The airplane meets the requirements of reference 2 in that the oscillations completely disappeared in less than one cycle and that there were no oscillations of the elevator itself following its release.

Static longitudinal stability.- The static longitudinal stability was measured by trimming the airplane at a given speed and then measuring the elevator control force and elevator position in steady flight at a series of speeds from the maximum allowable speed to the stall. The tests were made in the clean and in the landing condition, both power on and power off, at three different center-of-gravity positions. Variations of the elevator control force and elevator position with air-speed are presented in figure 6.

From figure 6 it can be seen that the elevator control force and elevator position variations with speed were stable in all conditions throughout the speed range up to the stall. At the upper end of the speed range in the power on, clean condition there was a rather rapid stable increase in the elevator force with increasing speed. In no condition was there any marked increase in pull force or up elevator angle during the approach to the stall.

In order to show the effects of the centering spring in the elevator control system, figure 7 presents the elevator control force as measured in the middle center-of-gravity position which includes the centering spring force, and the elevator control force with the calculated spring force subtracted from the measured force. Curves for two trim settings are shown in the figure. It can be seen that without the centering spring the elevator control force would have a neutral or slightly unstable variation near the stall. The addition of the small effect of the spring changed the neutral variation to a slightly stable variation.

The stick-fixed neutral points were determined by taking the slopes of elevator position against normal-force coefficient C_N as shown in figure 8, and plotting these slopes against center-of-gravity position as shown in figure 9. The center-of-gravity position at which the slope $d\delta_e/dC_N$ is equal to zero is defined as the stick-fixed neutral

point. The requirements state that the stick-fixed neutral point be behind the most rearward allowable center-of-gravity position.

Because of the large extrapolation necessary, it is impossible to determine the neutral point accurately if it is located well behind the most rearward center of gravity tested. Since the tests show that the stick-fixed neutral points for the Bonanza were, generally, well behind the most rearward test center of gravity, all values given for neutral points in the following discussion must be considered to be approximate.

In the power on, clean condition the airplane stick-fixed neutral point was well behind the most rearward allowable center-of-gravity position, varying from approximately 38 percent mean aerodynamic chord at $C_N = 1.0$ to approximately 48 percent mean aerodynamic chord at $C_N = 0.2$. The increase in slope of the curves in figure 8(a) at low values of C_N indicate a sudden rearward movement of the neutral point with decrease in C_N . This effect may be caused by stabilizer twist resulting from the large down elevator deflections required for trim at high speeds. Such a condition could also cause the large increase in force at high speeds noted previously.

In the power off, clean condition the stick-fixed neutral point remained at 36 percent mean aerodynamic chord for all values of normal-force coefficient tested.

With the landing flaps and gear down and with the power on, the stick-fixed neutral point was at approximately 50 percent mean aerodynamic chord at $C_N = 0.6$, and moved forward to 33 percent mean aerodynamic chord at $C_N = 1.4$. In the power off, landing condition the neutral point was located at approximately 39 percent mean aerodynamic chord for all values of normal-force coefficient.

Longitudinal control.- The longitudinal control characteristics were measured by performing steady pull-ups, push-downs, and turns at various speeds and center-of-gravity locations and measuring the elevator control force. Plots of the elevator control force against g are shown in figures 10 and 11. From figure 10 it can be seen that the variation of elevator force with g is linear, falling off only when the airplane approaches the stall. The variation of force per g with center-of-gravity position obtained from figure 10 was extrapolated to give the force per g values at the most forward and rearward allowable center-of-gravity positions. The values of 21 pounds per g to 10 pounds per g determined in this manner were considered to be in a satisfactory range.

Figure 11 shows the variation in elevator force with g throughout the speed range. Changing the speed had very little effect on the force per g variation.

The linearity of the force per g curves and the variation of force per g with speed was investigated carefully because a reduction in force per g might account for structural failure caused by excessive g being inadvertently applied during high-speed pull-outs. There was no indication that the force per g would tend to become low even at the highest speed tested.

Longitudinal control in take-off and landing.- The take-off and landing characteristics were investigated at all center-of-gravity positions tested. During the take-off run at the most forward center-of-gravity position tested, 21.8 percent mean aerodynamic chord, it was possible to pitch the airplane to its maximum ground angle of 14° at speeds below the take-off speed. At a rearward center-of-gravity position enough elevator control was available to pitch and maintain the airplane at an angle of attack considerably beyond the stall. At this angle of attack, insufficient power is available to climb or accelerate the airplane in a normal manner. These characteristics could contribute to take-off accidents by pilots of limited experience. For example, the use of a large up-elevator deflection could result in the airplane not clearing an obstacle at the end of the runway.

The maximum elevator angle measured during landing was 19.9° up. The pilot stated that there was enough elevator control to stall the airplane prior to the touchdown. The maximum elevator control force used in landing, 10 pounds, was well within the 50-pound limit prescribed by reference 2.

Longitudinal trim characteristics.- The change in elevator force for trim required by change in power was determined by trimming the airplane at 77 miles per hour in the power-off, landing condition, and then applying full power. The change in force required was 15 pounds push. The test was repeated in the clean condition, and in this case a 20-pound push force was required.

The elevator trim tab control was considered satisfactory.

Lateral Stability and Control

Dynamic lateral stability.- The dynamic lateral stability was tested by trimming the airplane at 160 and 130 miles per hour in the clean condition and abruptly moving the rudder and then releasing all of the controls. Time histories of the resulting oscillations are presented in figure 12. The period of these oscillations was approximately 2.5 seconds at 130 miles per hour and 1.8 seconds at 160 miles per hour, and approximately $1\frac{1}{2}$ cycles at 130 miles per hour and 1 cycle at 160 miles per hour are required to damp to one-half amplitude. An analysis of the oscillations showed that there was a reduction in damping as the amplitude of the oscillations became smaller. In the previous

tests of light airplanes (reference 1) the periods of the lateral oscillations following rudder kicks varied from 2 to 8 seconds. The cycles to damp to one-half amplitude varied from 0.2 to 0.6 cycles.

The comparison shows that the Bonanza airplane takes from $1\frac{1}{2}$ to 7 times the number of cycles to damp to half amplitude, and therefore it has less lateral damping than most present-day light airplanes have. The characteristics of the lateral oscillations of the Bonanza meet the requirements of reference 2. However, the damping of the oscillations is unsatisfactory according to the later criterion of reference 3.

As a result of the low damping of the lateral oscillations, the Bonanza was subject to continuous oscillations in rough air, an example of which is shown in figure 13. The pilots stated that it was impossible to stop these rough air excited oscillations. This characteristic made instrument flying in rough air without a directional gyro or a artificial horizon unduly tiring because the rate of turn indicator was being continuously excited and required almost constant pilot attention.

Rudder and aileron trim characteristics.- The rudder position and force, and the aileron position and force and the sideslip angle were measured throughout the speed range and are shown in figure 14. It can be noted from figure 14 that the rudder position and force for the power-on, clean condition and landing condition become high at the lower speeds, the rudder force amounting to 65 pounds in the power-on, landing condition. Since there is no rudder trim device, there is no way to reduce this force.

In order to determine if there was sufficient control for the most critical condition for lateral trim, the airplane was flown with the most asymmetrical loading possible. The left gas tank was filled, and the right tank was left empty; also the left seat was occupied and the right seat was vacant. The rudder position and force and the aileron position and force for this condition are also shown in figure 14. There was sufficient control to trim the airplane, but again the rudder trim force was excessive.

The effect on the lateral and directional trim characteristics of the rudder-aileron coordinating spring is shown in figure 15. The curves represent the rudder and aileron forces as measured, which includes the spring force, and the rudder and aileron forces without the spring, which were obtained by subtracting the calculated spring force from the measured force. The comparison shows that less rudder force, but slightly more aileron force is required for trim at low speeds with the spring removed.

Aileron control characteristics.- The aileron control characteristics were measured by performing rudder-fixed aileron rolls in the clean and flaps-down conditions, both power on and power off. Time histories of typical aileron rolls are presented in figure 16. Values of the helix angle $\text{pb}/2V$, aileron force, and maximum sideslip angle plotted against total aileron deflection are shown in figure 17.

It can be seen that the aileron deflection never reached its maximum of 42° in these tests. This condition occurred because the chain stop, which was used to give a constant control wheel deflection during each roll, restricted the control wheel movement short of its maximum deflection, and because of cable stretch.

The rolling velocity varies smoothly with control deflection, the rolling acceleration is in the correct direction, and the maximum rolling velocity is obtained within 0.2 second after the controls reached their maximum deflection in all cases. A helix angle of 0.09 was obtained. The variation of aileron force with aileron position is a smooth curve and has a maximum value of 25 pounds at cruising speed. Therefore the aileron control characteristics meet all the requirements of reference 2.

Also shown in figure 17 is the maximum sideslip angle reached during the aileron rolls. Never does this sideslip angle exceed 20° and at cruising speed is approximately 5° . In this respect the airplane meets the requirements for yaw due to ailerons of reference 2. When the yaw due to aileron characteristics of the Bonanza are compared with the data in reference 1, it can be seen that the Bonanza is slightly better in this respect than the high-wing light airplanes tested previously. The maximum sideslip angle reached during full aileron rolls exceeded 20° for all the high-wing airplanes reported in reference 1. From this comparison it can be concluded that the Bonanza has slightly greater directional stability than all previously tested high-wing light airplanes.

Sideslip characteristics.- Results of tests of the sideslip characteristics of the Bonanza airplane are shown in figure 18. It can be seen from this figure that positive dihedral effect exists in the clean condition; that is, aileron control to depress the leading wing is required (figs. 18(a) and 18(b)). The dihedral effect is reduced in the power-off, flaps-down condition (fig. 18(c)). In the flaps-down, power-on condition, at 77 miles per hour the aileron-position variation indicates a slight negative dihedral effect, and the aileron-force variation, which includes the rudder-aileron coordinating spring force, indicates a positive stick-free dihedral effect (figure 18(d)). When the calculated spring force is subtracted from the measured aileron force, the force variation also indicates a negative dihedral effect. The spring serves the purpose of furnishing a slight stick-free positive

dihedral effect in the power-on, flaps-down condition. However, it must be noted that the effect of the spring is small.

The directional stability was in general satisfactory. The yawing moment due to sideslip was such that right rudder was required for left sideslip and left rudder required for right sideslip. The angle of sideslip was proportional to rudder deflections. A comparison of rudder deflection required for sideslip between the Bonanza and the light airplanes tested in reference 1 shows that the Bonanza is as strong as the best airplane previously tested in regard to directional stability.

The variation of elevator control with sideslip angle in figure 18 indicates a satisfactorily small pitching moment due to sideslip.

Rudder control.- Limited tests of the rudder required to overcome aileron yawing moment were conducted, and the results are shown in figure 19. Rolls into turns at an airspeed of 65 miles per hour in the power-on, clean condition using one-half ailerons were performed using various amounts of rudder. By plotting the sideslip angle against rudder deflection it is possible to determine the amount of rudder required to obtain a coordinated turn with zero sideslip. Similar tests were run with the rudder free, so that the only rudder control obtained was produced by the aileron-rudder coordinating spring. The results showed that the coordinating spring will supply on the order of one-tenth of the rudder required for one-half full-deflection aileron rolls. The term "coordinating spring" is therefore somewhat inappropriate inasmuch as a much stiffer spring would be required to provide proper control coordination in aileron rolls. Probably the main advantage of this spring is the previously noted increase in stick-free dihedral effect in the power-on, flaps-down condition.

Concerning the rudder control in take-off and landing, the pilot stated that in all instances there was ample rudder control to maintain directional control.

Stalling characteristics.- Records of stalling characteristics were obtained during stalls made in various manners. Time histories of these stalls are shown in figure 20.

It should be noted that the Bonanza is equipped with a mechanical stall warning system. The system consists of a small hinged flap or vane located at approximately the 80-percent chord of the wing and behind the stall strips. When the air flow at this location breaks down, the vane falls, and a warning is given in the cockpit. In the case of the test airplane, the warning was a flashing light located on the instrument panel. The pilots stated that when they made a point to watch the light, they noticed that the stall warning occurred a reasonable length

of time before the complete stall, and that it gave consistent warning for all the varied conditions of the stalls. The use of the flashing light as a warning was considered inadequate, however, because the pilot might not be looking at the instrument panel at the required moment.

Figure 20(a) is the time history of a stall performed in the power-on, clean condition with the center of gravity located at 29.3 percent of the mean aerodynamic chord. This stall, and all of the stalls presented in this paper, were initiated by slowly decreasing the airspeed while holding the wings level. Figure 20(a) shows the history of a stall followed by a normal recovery. Figures 20(b) and 20(c) are stalls done in the same condition and in the same manner with the exceptions that figure 20(b) is with power off and figure 20(c) is in the landing condition.

It can be seen from these first three time histories that there is little warning prior to the stall in the form of buffeting or in the form of an appreciable increase in stick movement or stick force. At the stall there is a rapid roll-off, together with some mild buffeting. The pilot starts his recovery when the roll-off starts, controlling the roll-off by the application of down elevator and rudder and aileron to oppose the roll. In spite of the prompt application of controls for recovery, a roll angle of 24° was reached in the power-on, clean condition.

Figures 20(d) and 20(e) are time histories of stalls in which the controls were fixed as long as possible during the rolling motion. These stalls were made in the same conditions mentioned previously. The airplane started the stalls with a small amount of left sideslip. The initial roll-off was to the right. This roll would continue to the right until the airplane was slipping to the right. Then the airplane reversed its direction of roll. The roll to the left continued until the airplane was slipping to the left again. The pilot stopped the action after 1 cycle because the airplane had reached an undesirable attitude. Recovery was made by applying down elevator.

Tuft studies were made of the right wing during a typical stall. The stall started at the trailing edge on the inboard section of the wing. The stall then spread over the section of the wing behind the stall strip. It continued to grow until it covered the entire inboard half of the wing, and remained in this condition until the roll-off started. At the roll-off the entire wing stalled. After the initial roll-off the outboard half of the wing would alternately stall and unstall, depending on the direction of the roll and sideslip.

Similar stalls were made in a forward center-of-gravity position, approximately 23 percent mean aerodynamic chord. More up elevator was required in this condition, which gave more warning of the approaching

stall than occurred when the stalls were done in the rearward center-of-gravity position. The roll-off was less abrupt, and the recovery was accomplished more easily in the forward center-of-gravity position.

Stalls were also made in which it was attempted to prolong the stall by holding full-up elevator. Time histories of this maneuver in the clean condition, both power on and power off, are shown in figures 20(f) and 20(g) and in the landing condition, power on, in figure 20(h). The center of gravity was located at 29.3 percent mean aerodynamic chord as before. In the clean condition it was found that the roll-off could be controlled by use of the aileron and rudder, or by use of the ailerons alone. Attempts to control the roll-off by use of the rudder alone were unsuccessful. In the landing condition, the roll-off was more violent than in the clean condition so that it was impossible to fly steadily in the stalled attitude. Recovery was made by applying down elevator.

It is of interest to note that in the clean condition and with the center of gravity in the rearward position, it was possible to control the roll and to pitch the airplane to a point where both wings were completely stalled. The pilot stated that it was very easy to control the airplane when it was in this condition. In several instances the airplane was held in this completely stalled condition, power off, while the airplane descended at a rate of approximately 3500 feet per minute. However, it is unlikely that this condition would ever be reached if a normal recovery were made after the stall.

In all cases there was little warning of the approaching stall except for the stall warning light. Also, the stall was always accompanied by a rapid roll-off.

CONTROL UNDER INSTRUMENT FLYING CONDITIONS

In addition to measuring the handling qualities, tests were made of the conditions that might lead to high-speed pull-outs and structural failure of the airplane. The items tested were the spiral divergence, the ability to recover from unusual attitudes while flying under a hood, and the speed increase in a steady dive. It was felt that these items might all be factors in instrument flying accidents.

Spiral divergence.- The spiral divergence was tested by trimming the airplane at various speeds, releasing the controls, and recording the resulting spiral divergence. This procedure was followed while the airspeed was controlled by moving the control wheel yoke and also when all controls were freed and the airspeed allowed to increase. Time histories of these spiral divergences are shown in figures 21 and 22.

Figure 21(a) is a time history of the spiral divergence which started at 68 miles per hour, and during which the airspeed was held constant. Since the airplane has no adjustable rudder trim device, the rudder moved to an out-of-trim position when the controls were released. In this case the rudder moved 8° to the left. While the airspeed was held constant the airplane diverged rapidly to the left. When the controls were released at cruising speed, figure 21(b), the rudder moved approximately 1° to the left and the airplane diverged slowly to the left. At the high speed, 180 miles per hour, the airplane was in trim with the controls free, and the divergence disappeared, figure 21(c). Only a steady turn was recorded.

From the high-speed time history it can be concluded that the airplane has inherent spiral stability at high speeds. It is felt that the divergence at low speeds is primarily the result of the lack of directional trim. While there is no way to adjust the directional trim in flight, it must be remembered that the fixed bent tabs on the aileron afford a means of adjusting somewhat the airspeed at which lateral trim will exist.

When the airspeed was allowed to increase during the tests, the divergence was more rapid. In the first case, figure 22(a), the controls were released at 70 miles per hour. From the incomplete record of this test it can be seen that the airspeed reached a constant value of 100 miles per hour, but that the normal acceleration was increasing steadily and reached approximately $2\frac{1}{2}g$ before the records were turned off. When the controls were released at 100 miles per hour, figure 22(b), the airspeed increased to 140 miles per hour in 36 seconds. The normal acceleration reached approximately $1\frac{3}{4}g$ by that time. The first case of divergence to the right was encountered when the controls were released at 180 miles per hour and the airspeed allowed to increase, figure 22(c). The airspeed increased to 195 miles per hour, accompanied by a steady increase in normal acceleration, before the test was terminated.

Blind flying recoveries.- In the blind flying tests the vision of the pilot was restricted by the use of amber glass on all windows on the airplane, and blue goggles worn by the pilot. This arrangement enabled the pilot to refer to the airplane instruments, but he could not see outside the airplane. The co-pilot would place the airplane in some large displacement from level flight. The records would then be started, and the controls turned over to the pilot at the same instant. The pilot would look up at the instruments and start his corrective action.

The airplane was equipped with a rate of turn indicator, a ball-bank indicator and an airspeed indicator for use during blind flying. The pilot used an attitude method for the recoveries in which the attitude of the airplane is determined from the instrument readings, and the controls used in a more or less coordinated manner to regain level flight at the cruising speed.

From figure 23 it can be seen that it generally took the pilot 0.5 second to start correcting the attitude of the airplane. In all cases he was able to return the airplane to level flight with very little control movement without the airplane exceeding the airspeed or acceleration limits. It should be noted that the pilot who made these recoveries was an experienced instrument pilot.

Speed increase.- Examples of the speed increase of the airplane in steady dives are shown in figure 24. These runs were started with a power setting for level flight at 140 miles per hour. The power was held constant throughout the test. The airplane was placed in a dive and held at the same pitch angle until the airplane reached its terminal velocity or reached the maximum allowable velocity. The initial rate of increase in the velocity is a function of gravity alone. The drag of the airplane determines the terminal velocity corresponding to the angle of the dive. Figure 24 shows that when the airplane was pitched down 5° the velocity exponentially approached 174 miles per hour. In the 10° pitch-down dive the airplane exceeded its maximum allowable velocity of 202 miles per hour in 40 seconds; in the 14° dive the maximum allowable velocity was exceeded in 22 seconds.

The ease with which the Bonanza airplane can exceed its maximum allowable airspeed could make it difficult for an inexperienced pilot to maintain a safe speed.

CONCLUSIONS

1. The airplane satisfactorily meets most present-day flying qualities requirements. The only deficiencies in that respect are the marginal damping of the lateral oscillations, the lack of aerodynamic warning prior to the stall, and the rapid roll-off at the stall.
2. Factors which might affect the instrument flying qualities are the effect of the continuous lateral oscillations on the rate-of-turn indicator during rough-air conditions, the rapid spiral divergence at low speeds, and the ease with which the airplane can exceed its maximum allowable airspeed in relatively gradual dives.

3. Under instrument flying conditions, recoveries from unusual attitudes can be made with very little control movement.

4. The lack of aerodynamic stall warning and the rapid roll-off at the stall could contribute to stall-spin accidents. Other take-off accidents could be caused by the fact that the airplane could be pitched to an angle of attack beyond the stall where sufficient power to climb was not available.

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TABLE I

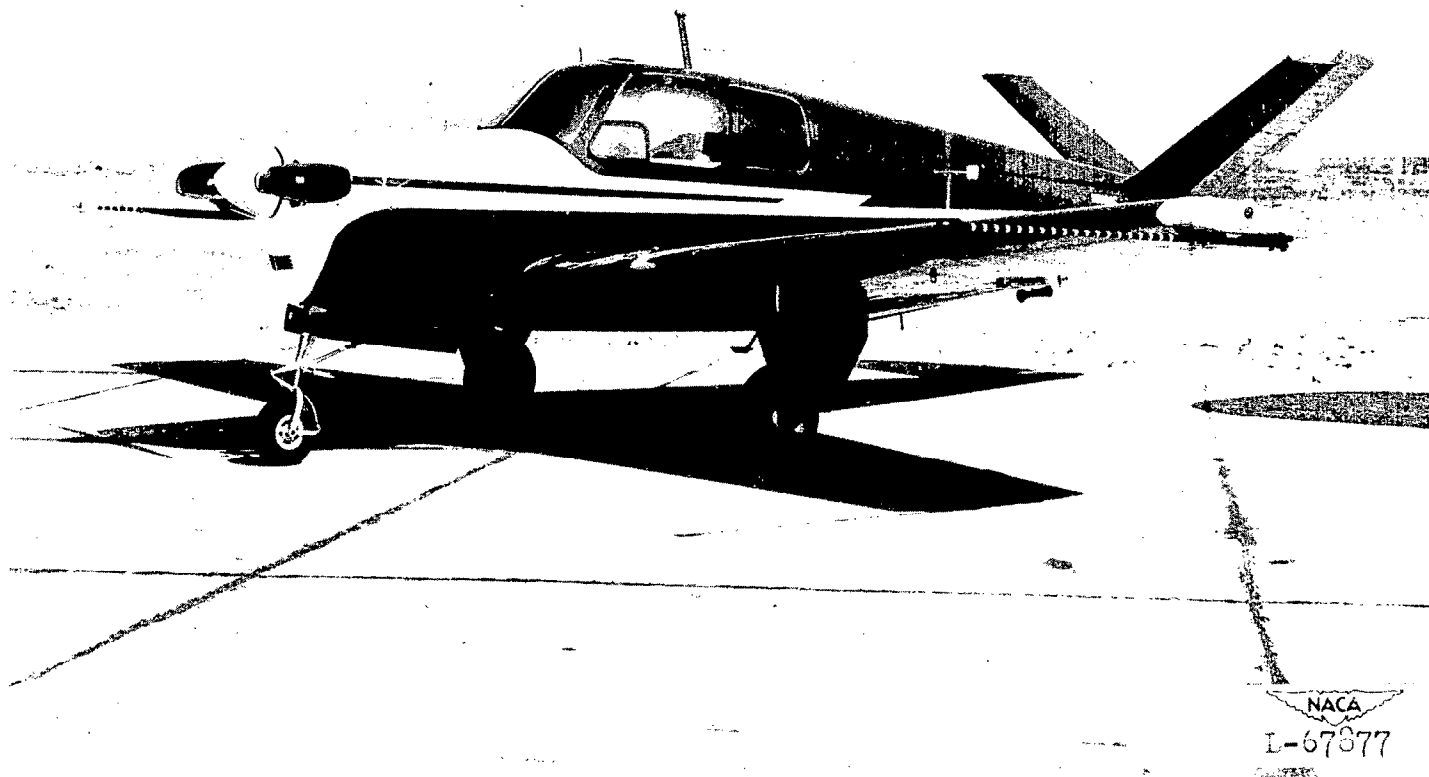
PHYSICAL CHARACTERISTICS OF BEECH B-35 BONANZA AIRPLANE

Engine	Continental E-185-1 or 8
Propeller	Beech electric constant speed; 2 blades
Wing airfoil section at root	NACA 23016.5
Wing incidence at root, deg	4
Wing dihedral, deg	6
Washout, deg	3
Wing area, sq ft	177.6
Wing span, ft	32.82
Mean aerodynamic chord, in.	65.3
Aileron area, sq ft	11.5
Flap area, sq ft	21.3
Empennage area, sq ft	36.145
Stabilizer area (to center line of fuselage), sq ft	21.8
Elevator area, sq ft	14.345
Tail dihedral, deg	30
Tail incidence, deg	-2
Tail span (not projected span), in.	145
Tail mean aerodynamic chord, in.	36.5
Center-of-gravity limits, percent M.A.C.:	
At 2140 pounds	14.1 to 28.6
At 2650 pounds	26.0 to 27.0





NACA RM S151F18

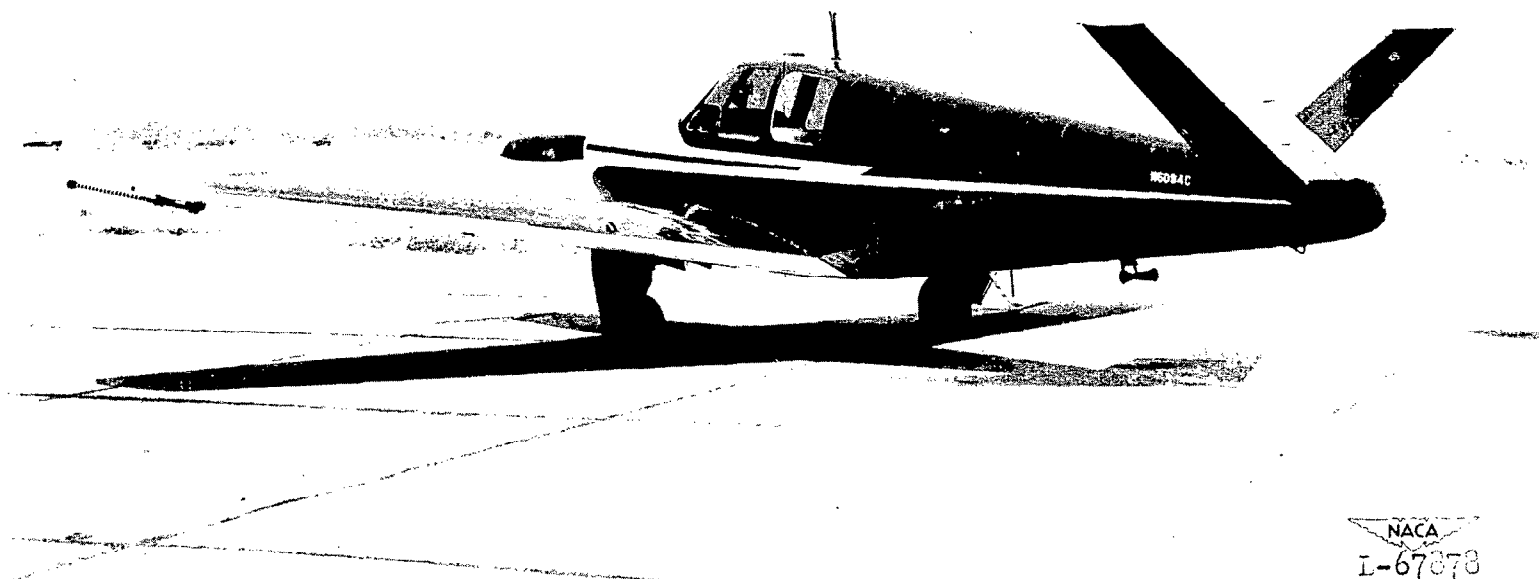


(a) Three-quarter front view.

Figure 1.- Beech B-35 Bonanza airplane.



NACA RM S151F18



(b) Three-quarter rear view.

Figure 1.- Concluded.



NACA RM S151F18

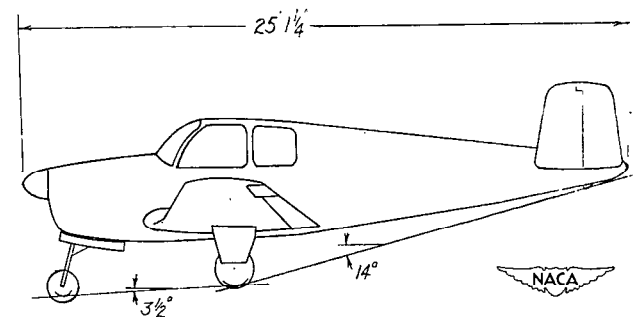
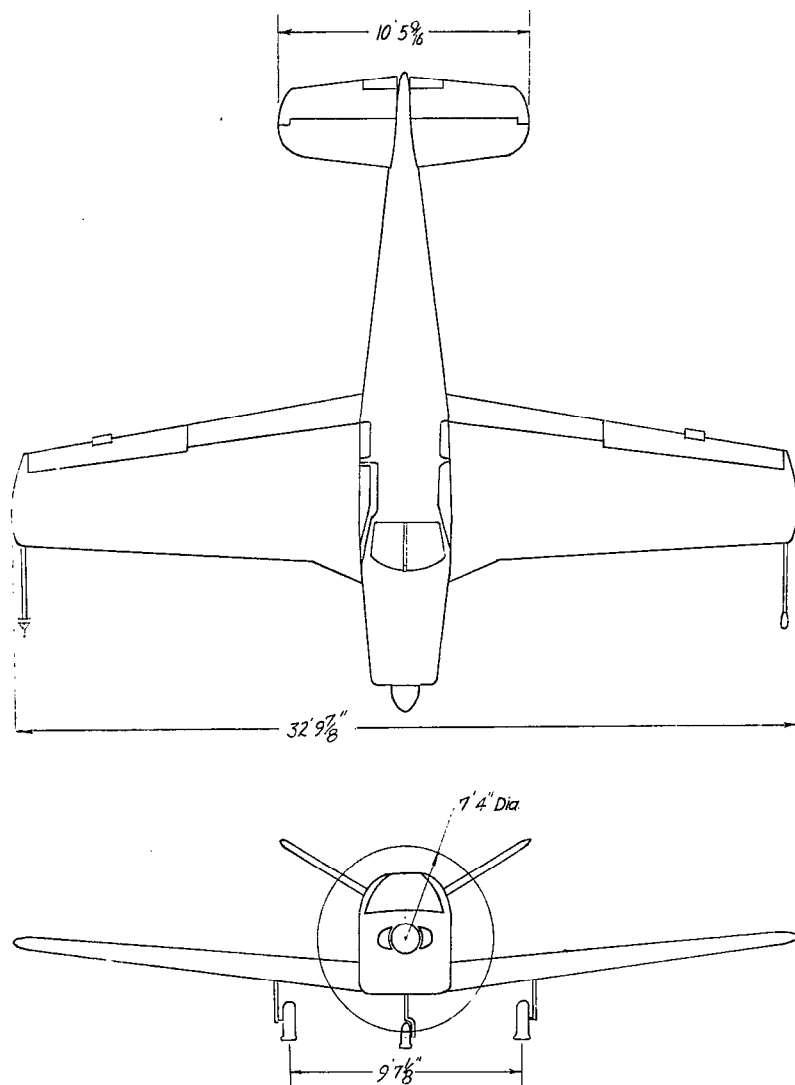
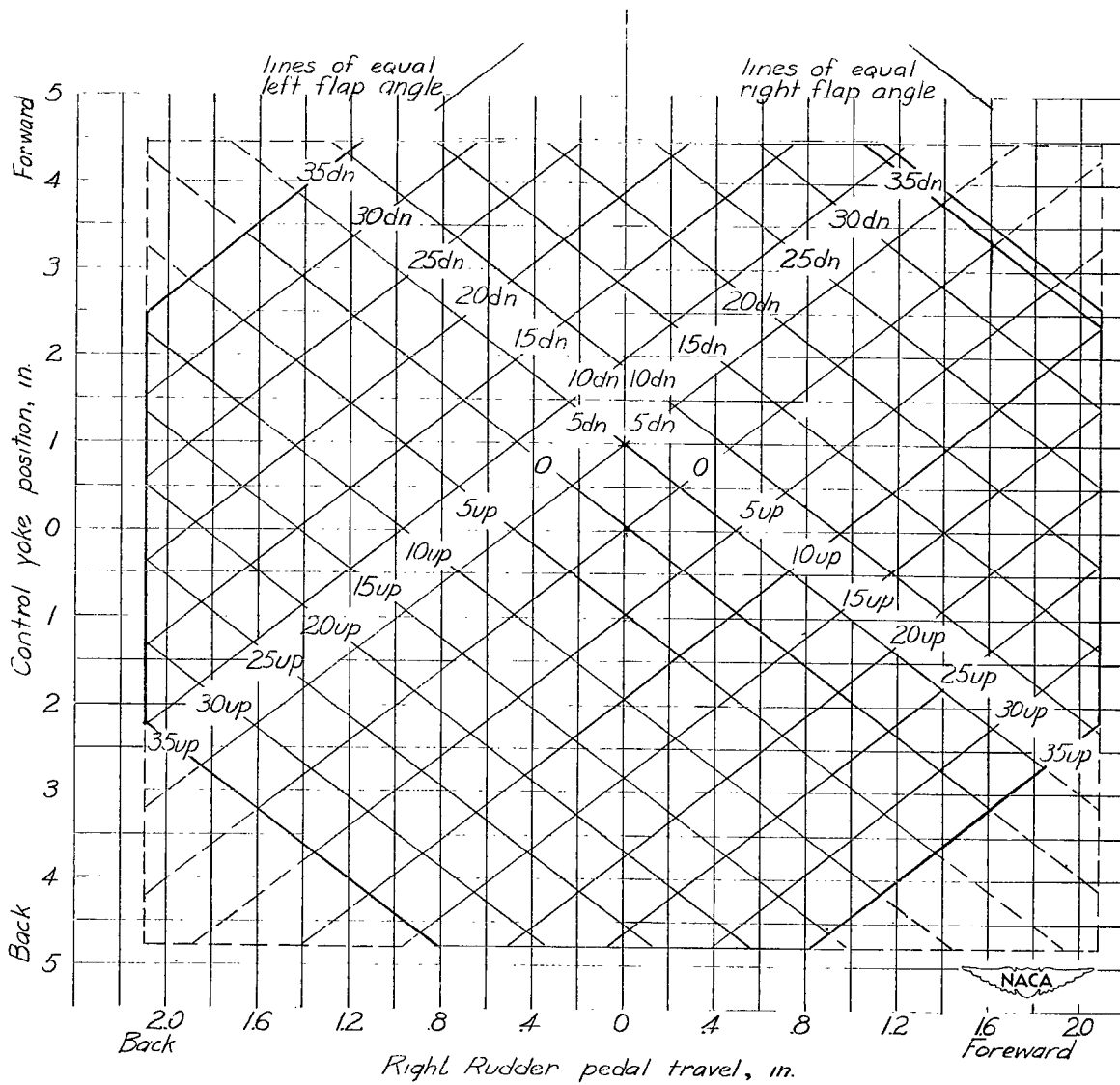
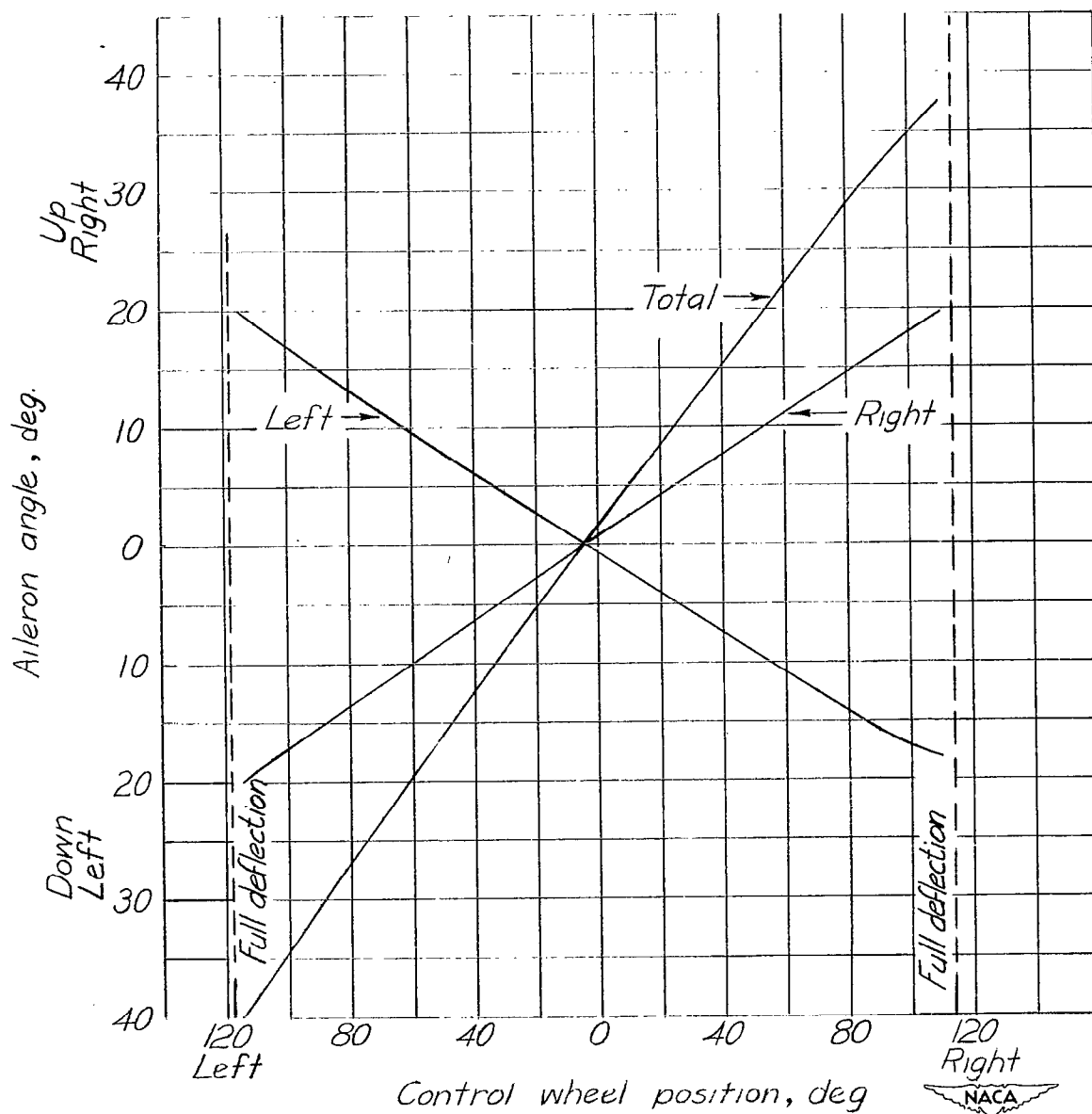


Figure 2.- Three-view drawing of the Beech B-35 Bonanza airplane.



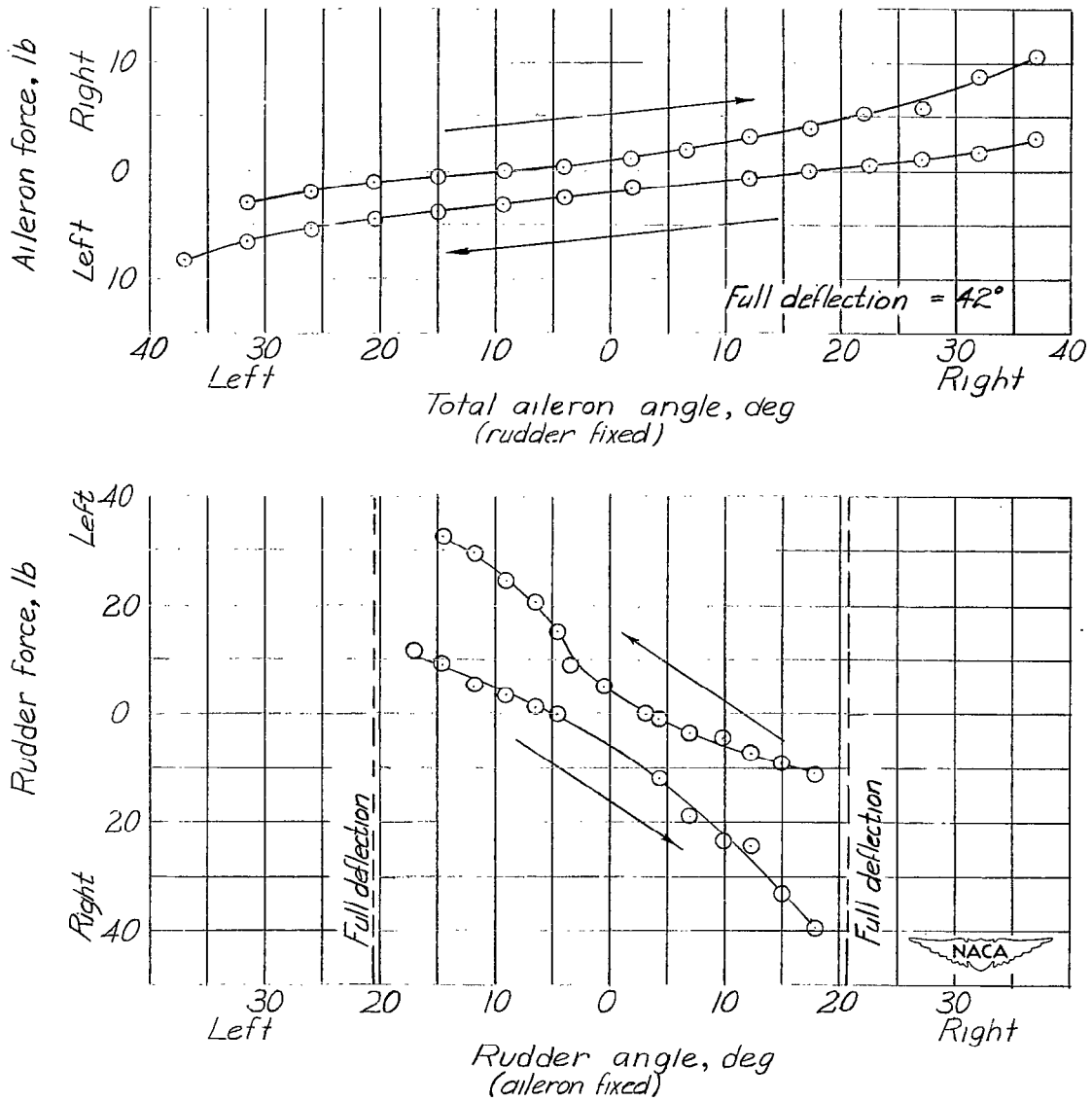
(a) Elevator-rudder control.

Figure 3.- Variation of control flap position with pilot's control position for the Beech B-35 Bonanza airplane.



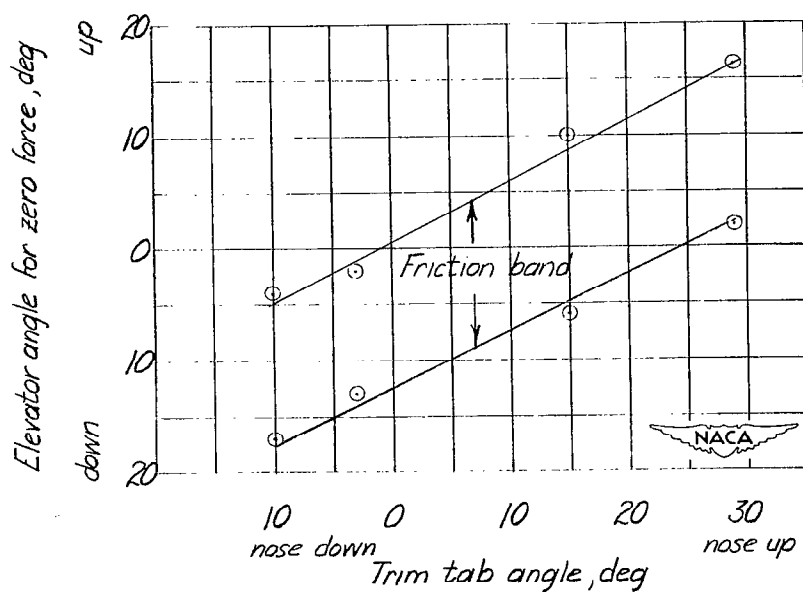
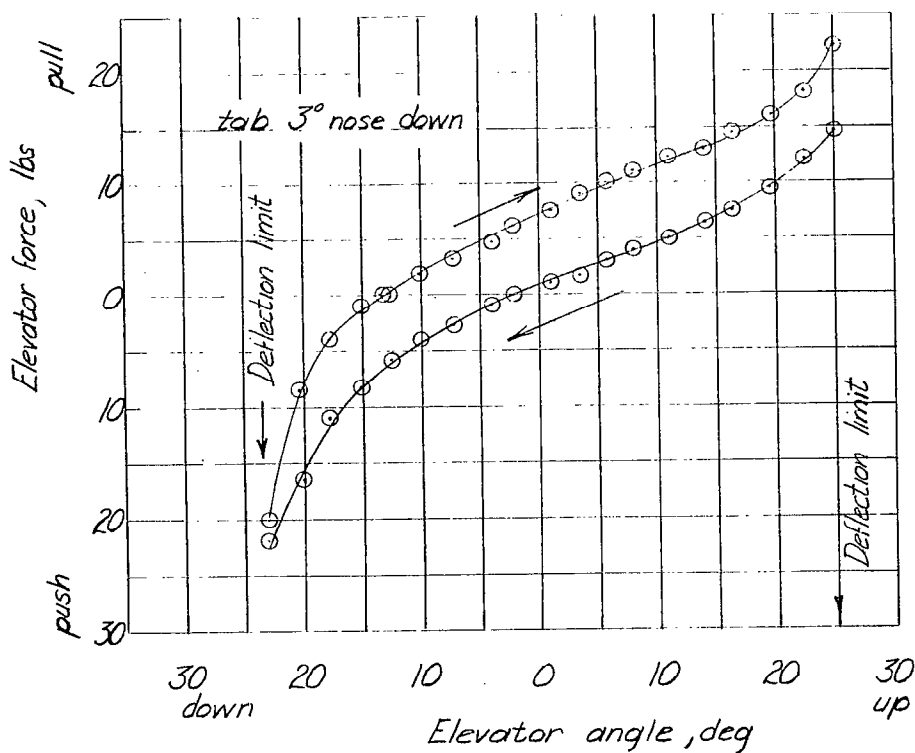
(b) Aileron control.

Figure 3.- Concluded.



(a) Aileron and rudder control.

Figure 4.- Variation of control force with flap position showing the control system friction and spring forces for the Beech B-35 Bonanza airplane.



(b) Elevator control.

Figure 4.- Concluded.

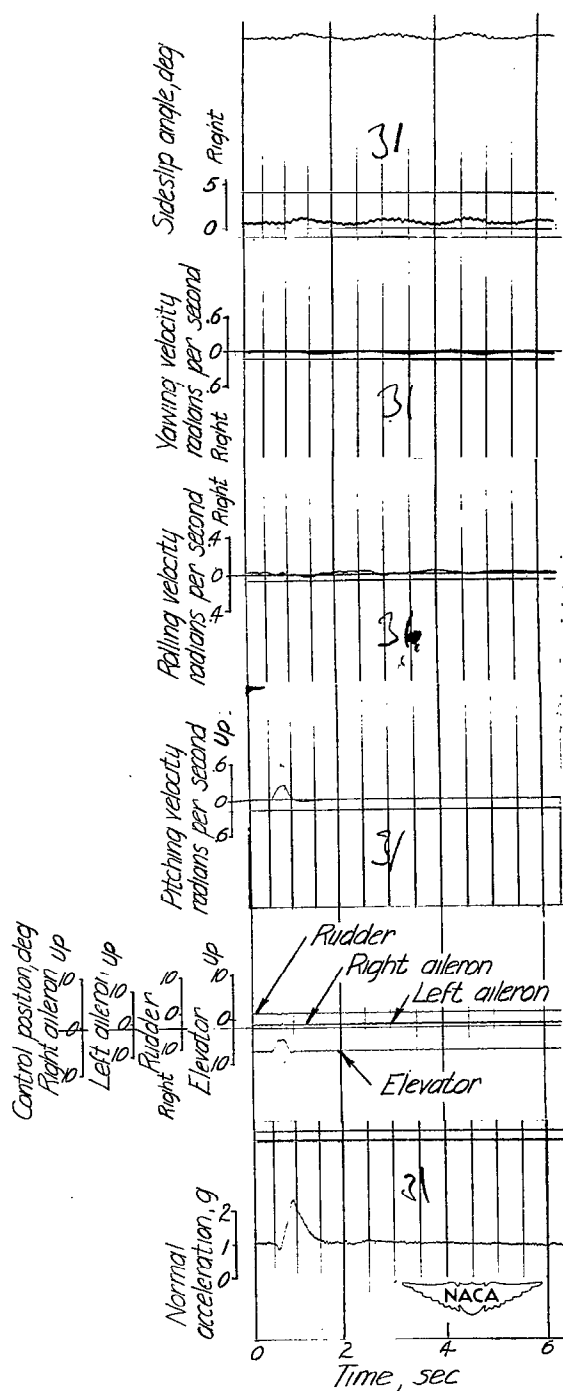
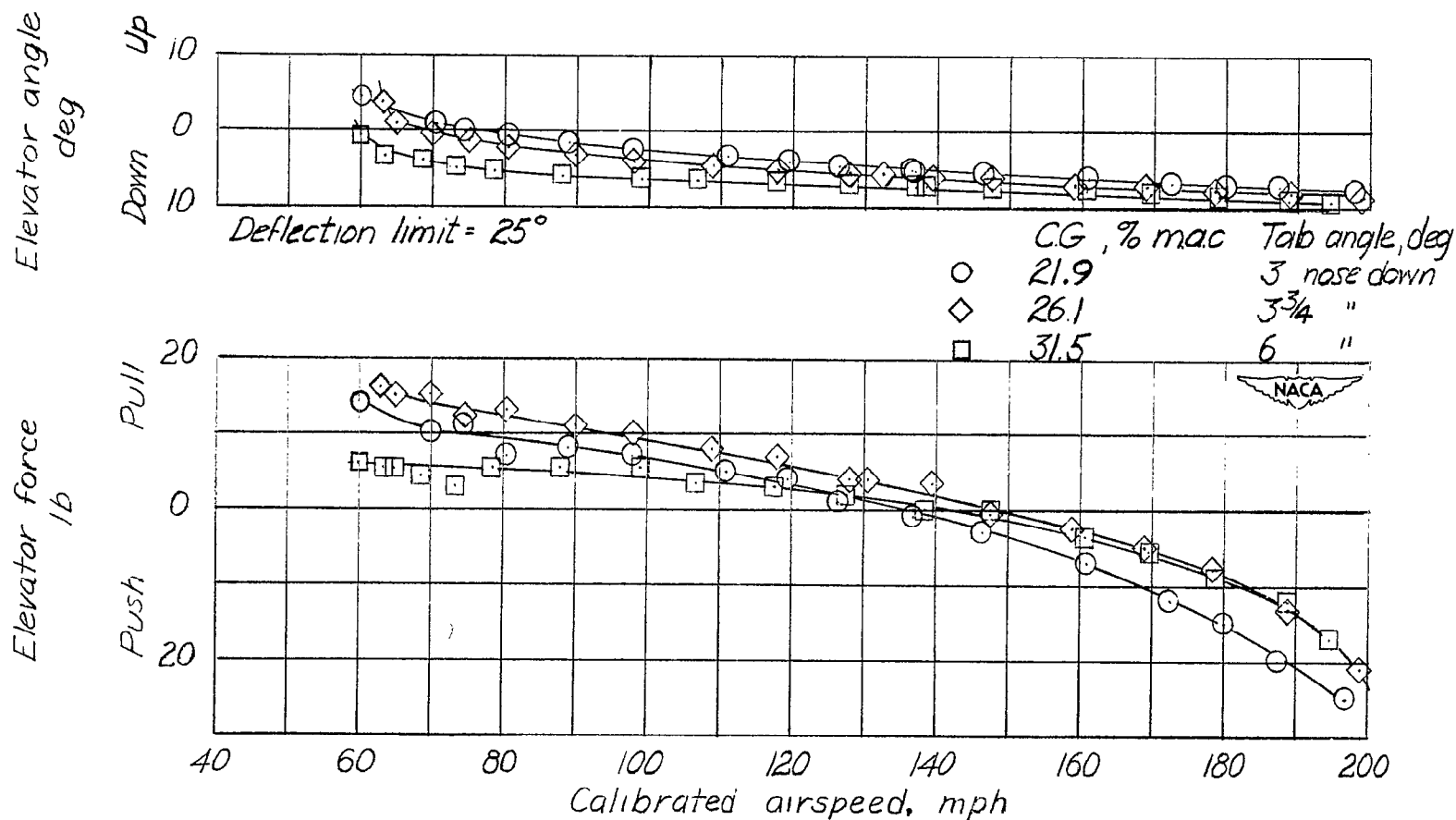
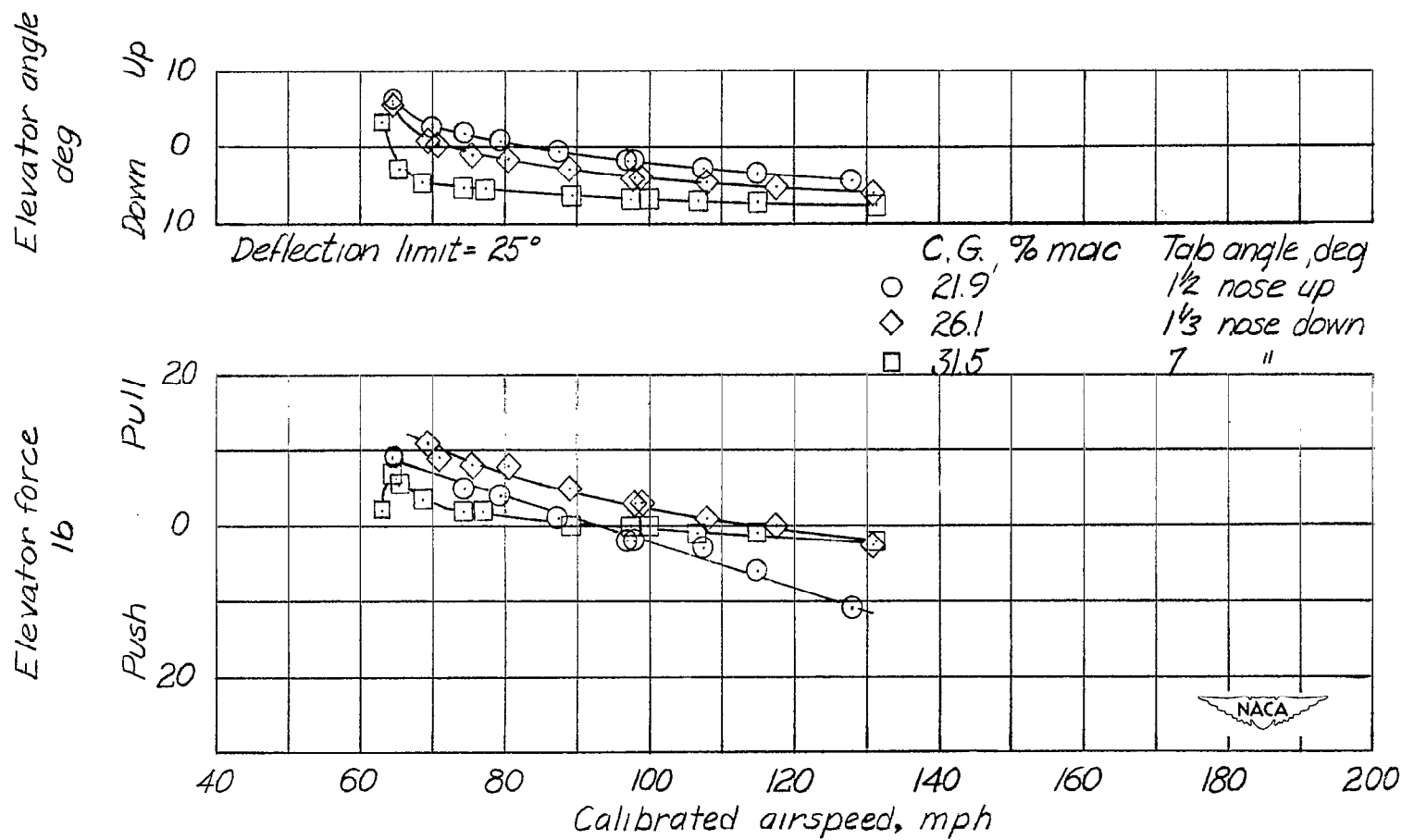
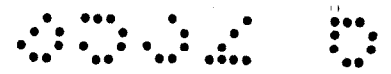


Figure 5.- Time history of the control free oscillations following an abrupt movement and release of the elevator. Airplane in the power on, clean condition; airspeed = 180 miles per hour. Center of gravity located at 26.1 percent mean aerodynamic chord; Beech B-35 Bonanza airplane.



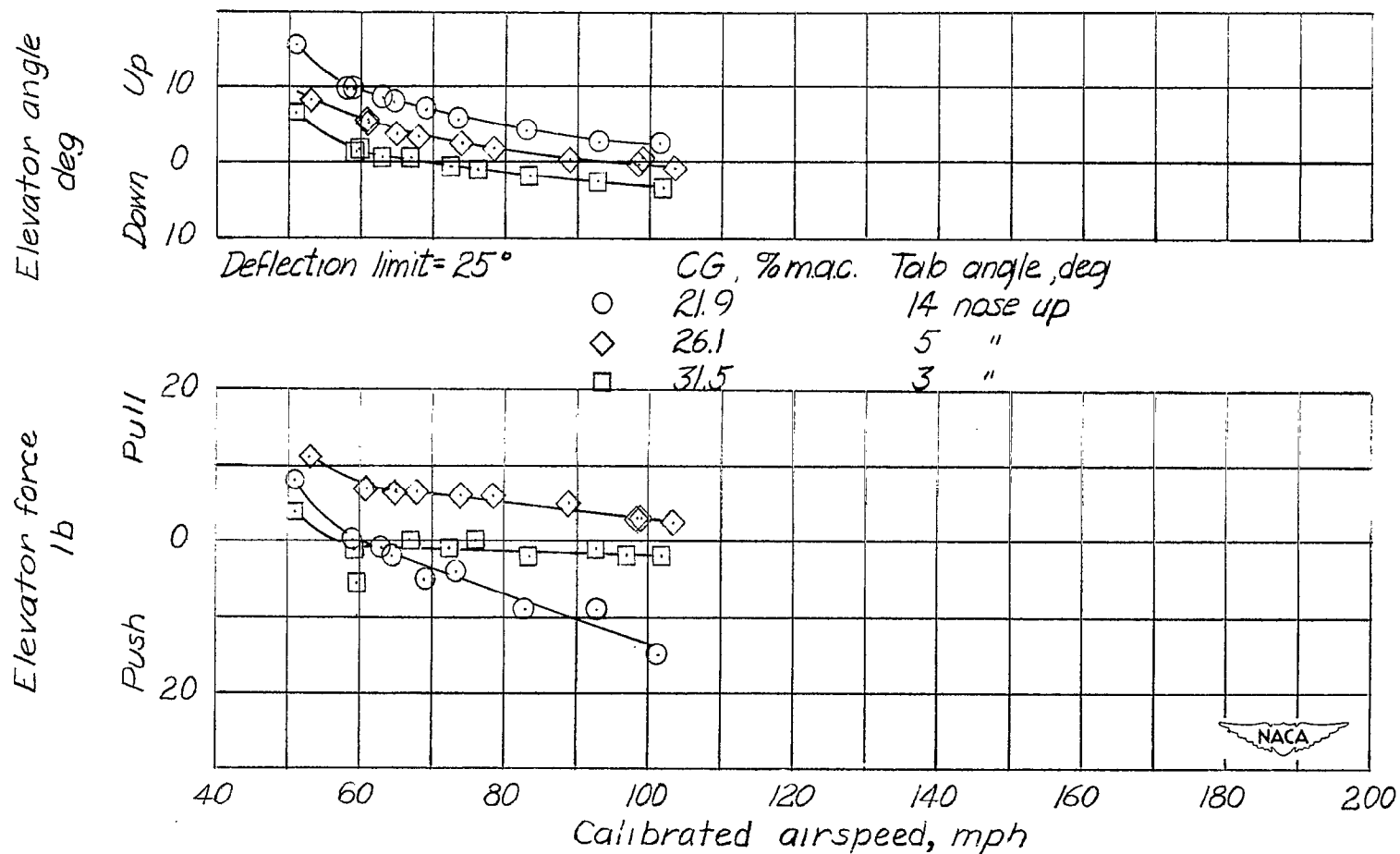
(a) Power on (cruising power, 22 in. Hg at 2050 rpm); clean condition.

Figure 6.- Static longitudinal stability characteristics of the Beech B-35 Bonanza airplane.



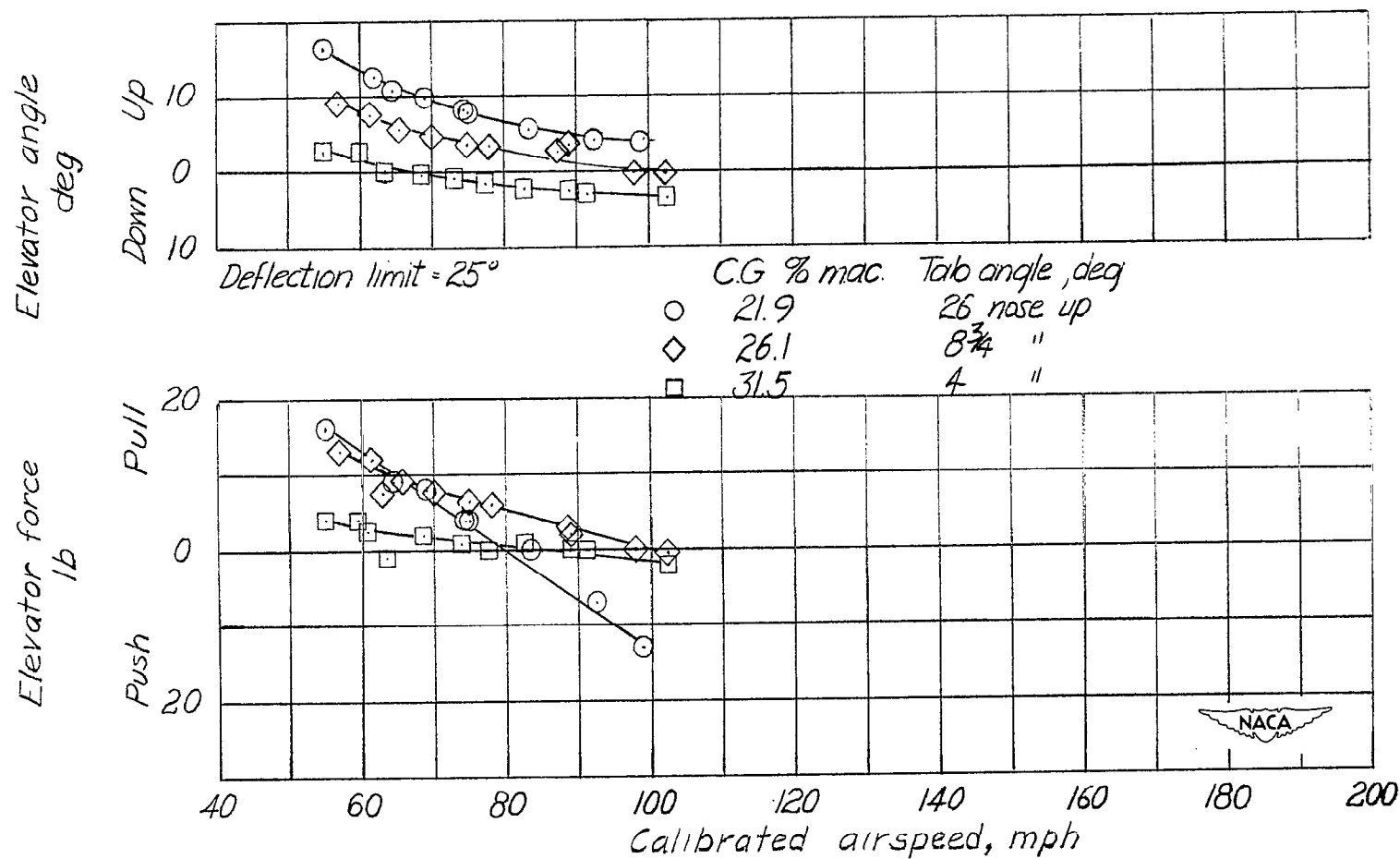
(b) Power off; clean condition.

Figure 6.- Continued.



(c) Power on (22 in. Hg at 2050 rpm); flaps and gear down.

Figure 6.- Continued.



(d) Power off; flaps and gear down.

Figure 6.- Concluded.

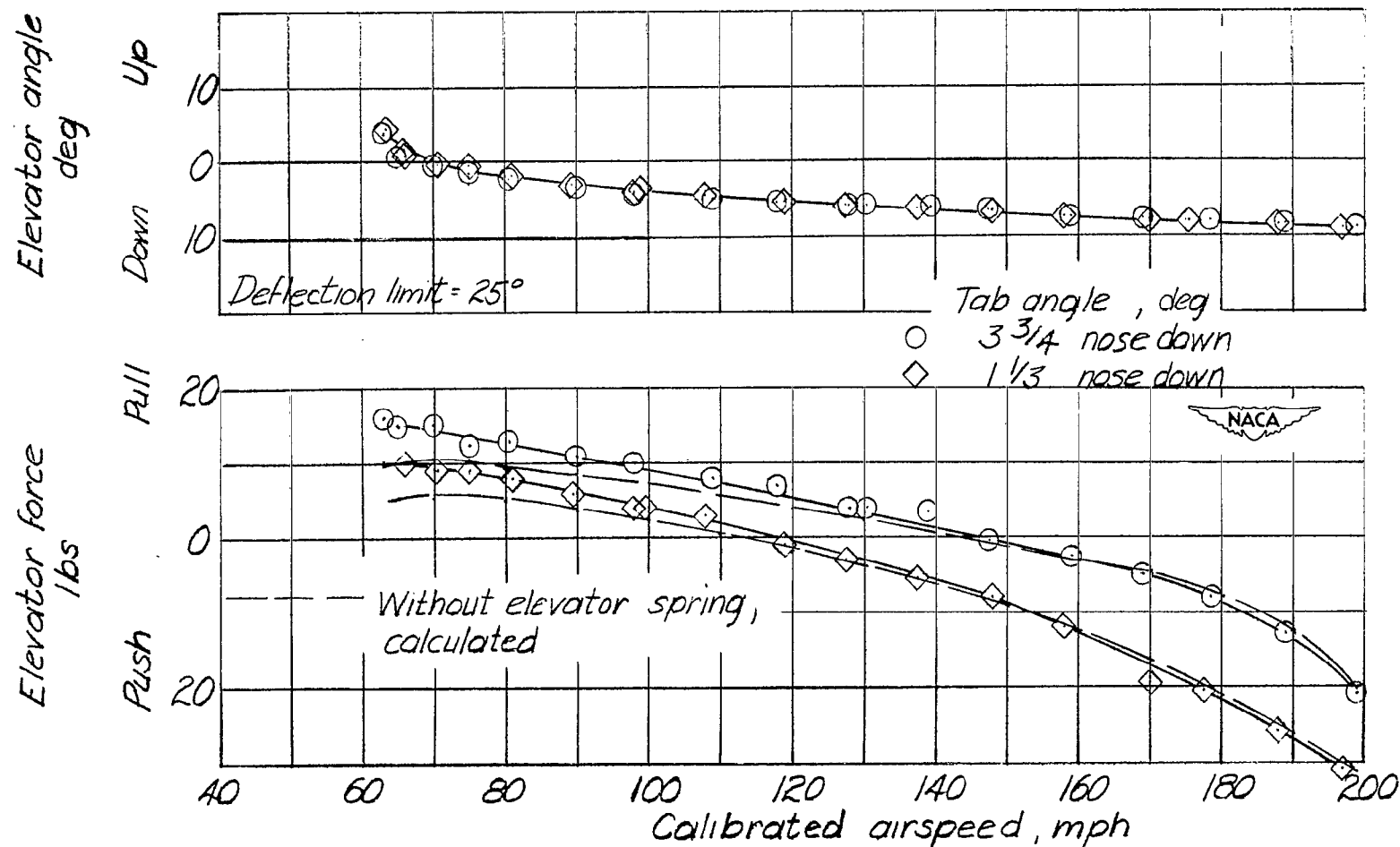


Figure 7.- Variation of elevator position and force with airspeed for two different trim tab settings for the Beech B-35 Bonanza airplane in power on (cruising power, 22 in. Hg at 2050 rpm); clean condition.

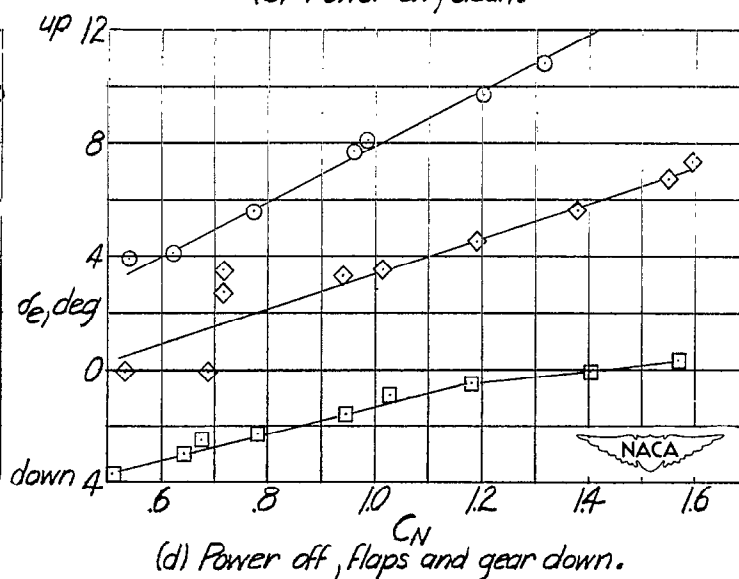
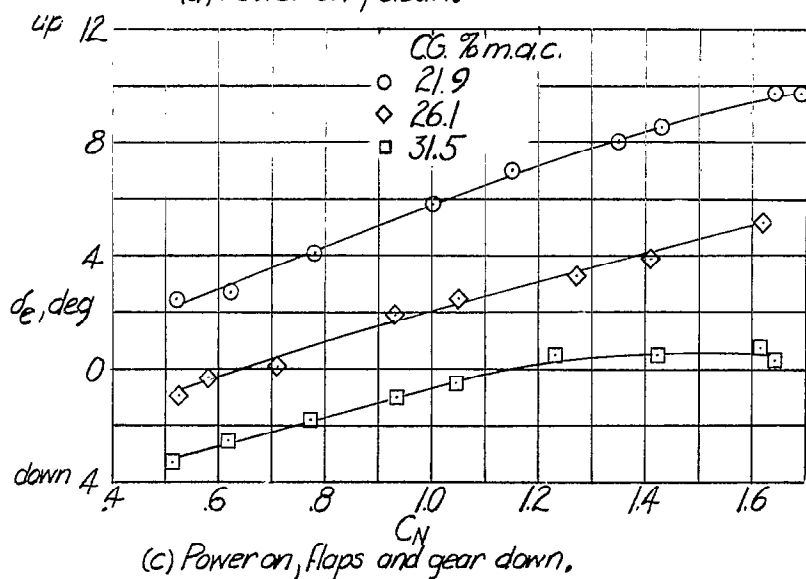
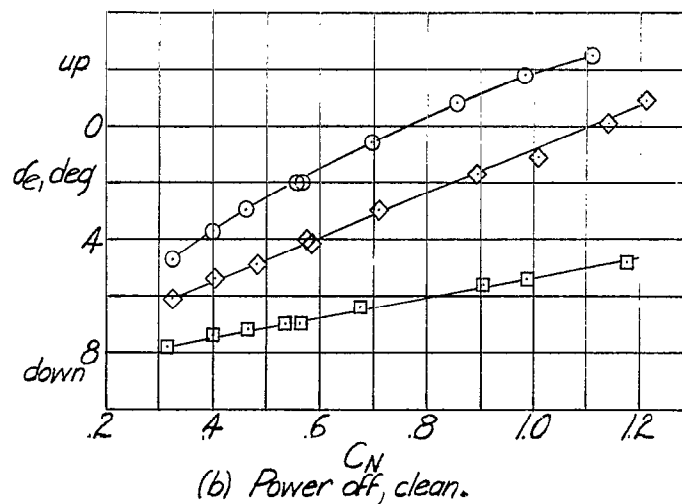
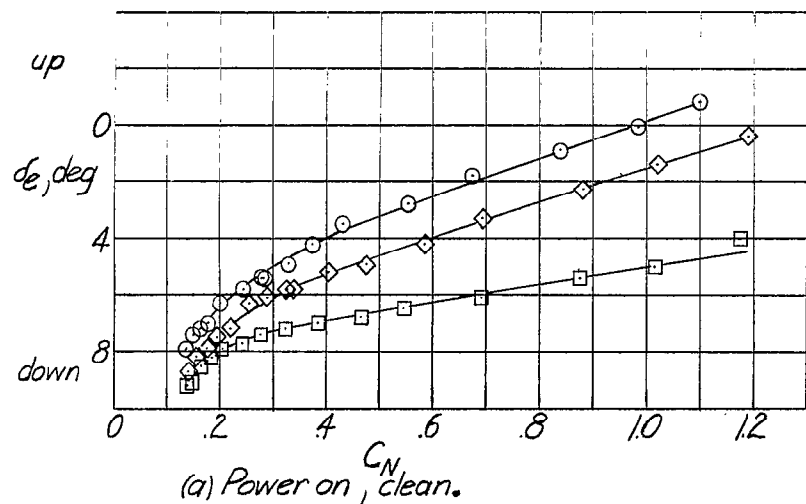


Figure 8.- Variation of elevator angle with normal-force coefficient at various centers of gravity.

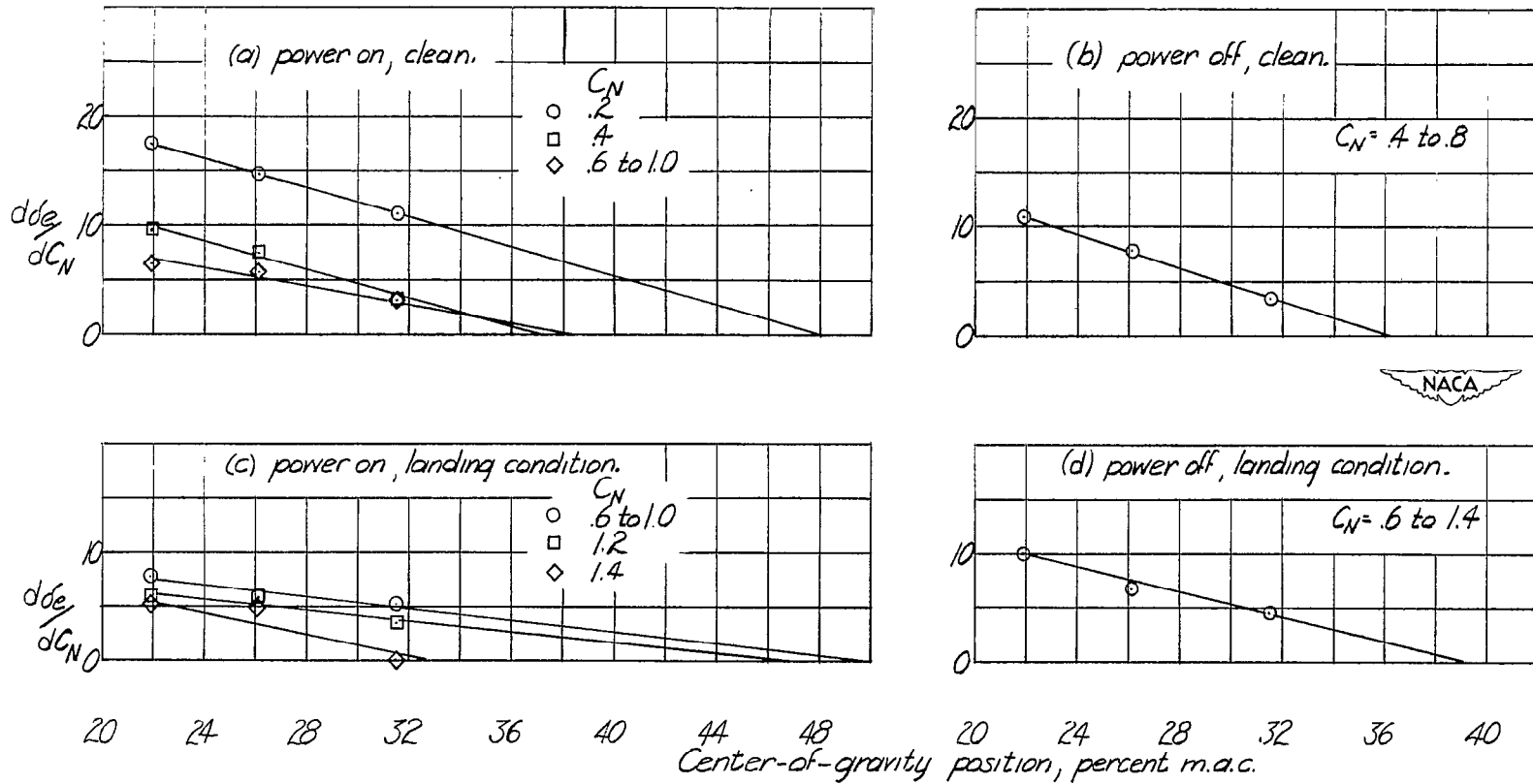
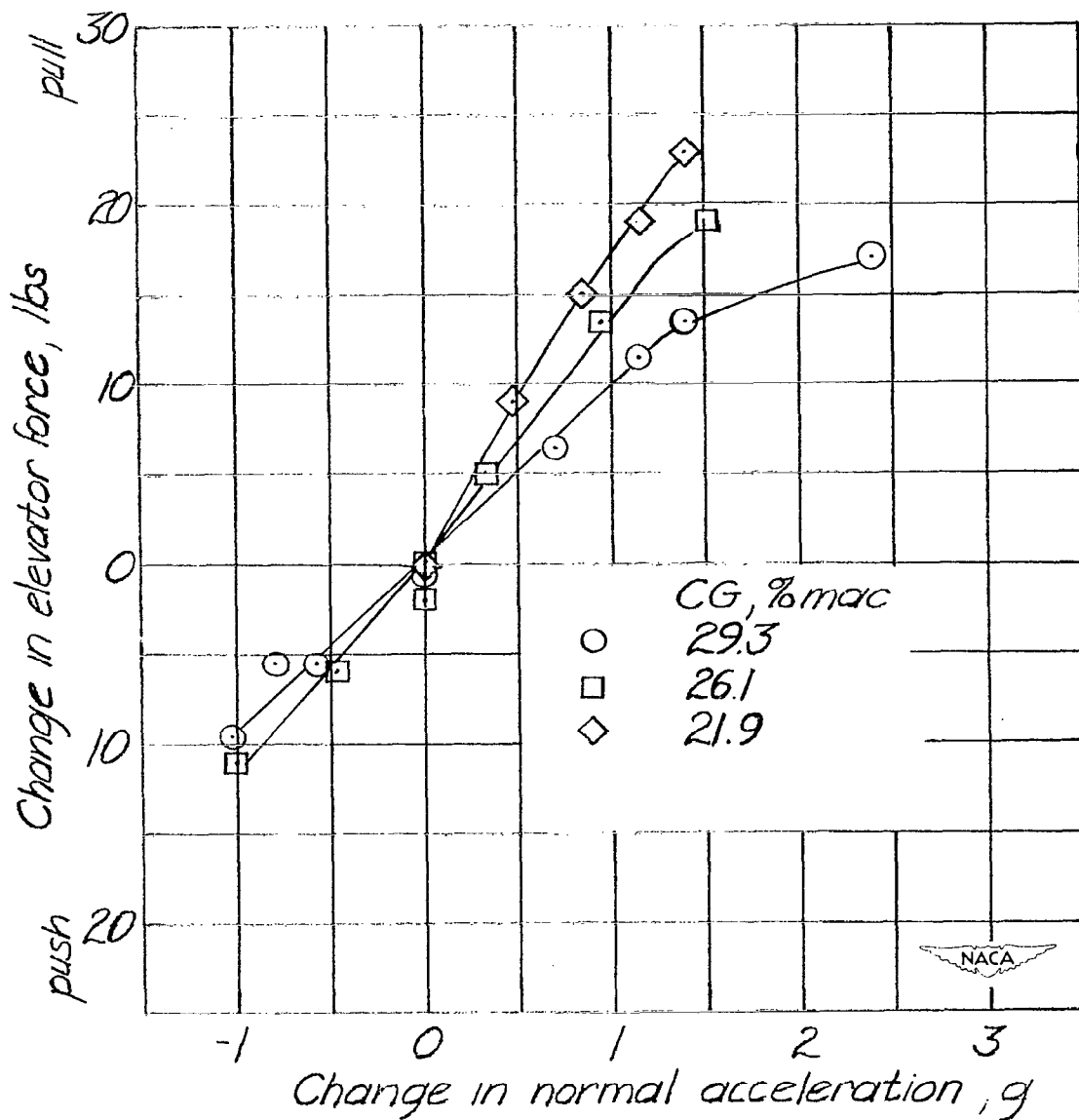
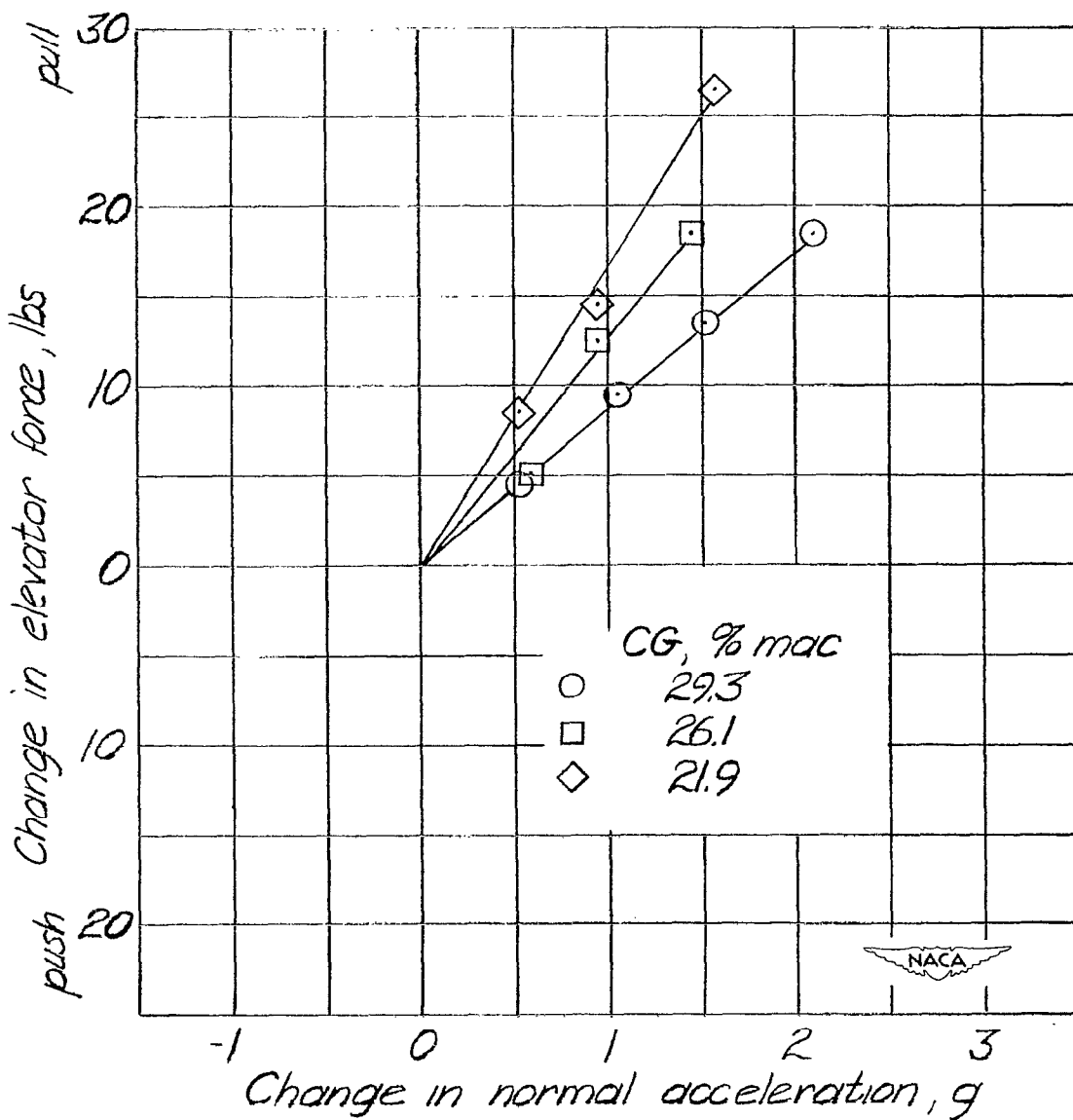


Figure 9.- Stick-fixed neutral points of the Beech B-35 Bonanza airplane.



(a) In steady pull-up and push-down maneuvers.

Figure 10.- Variation of elevator force with normal acceleration for three different center-of-gravity positions in the power-on clean condition at approximately 130 miles per hour for the Beech B-35 Bonanza airplane.



(b) In steady turns.

Figure 10.- Concluded.

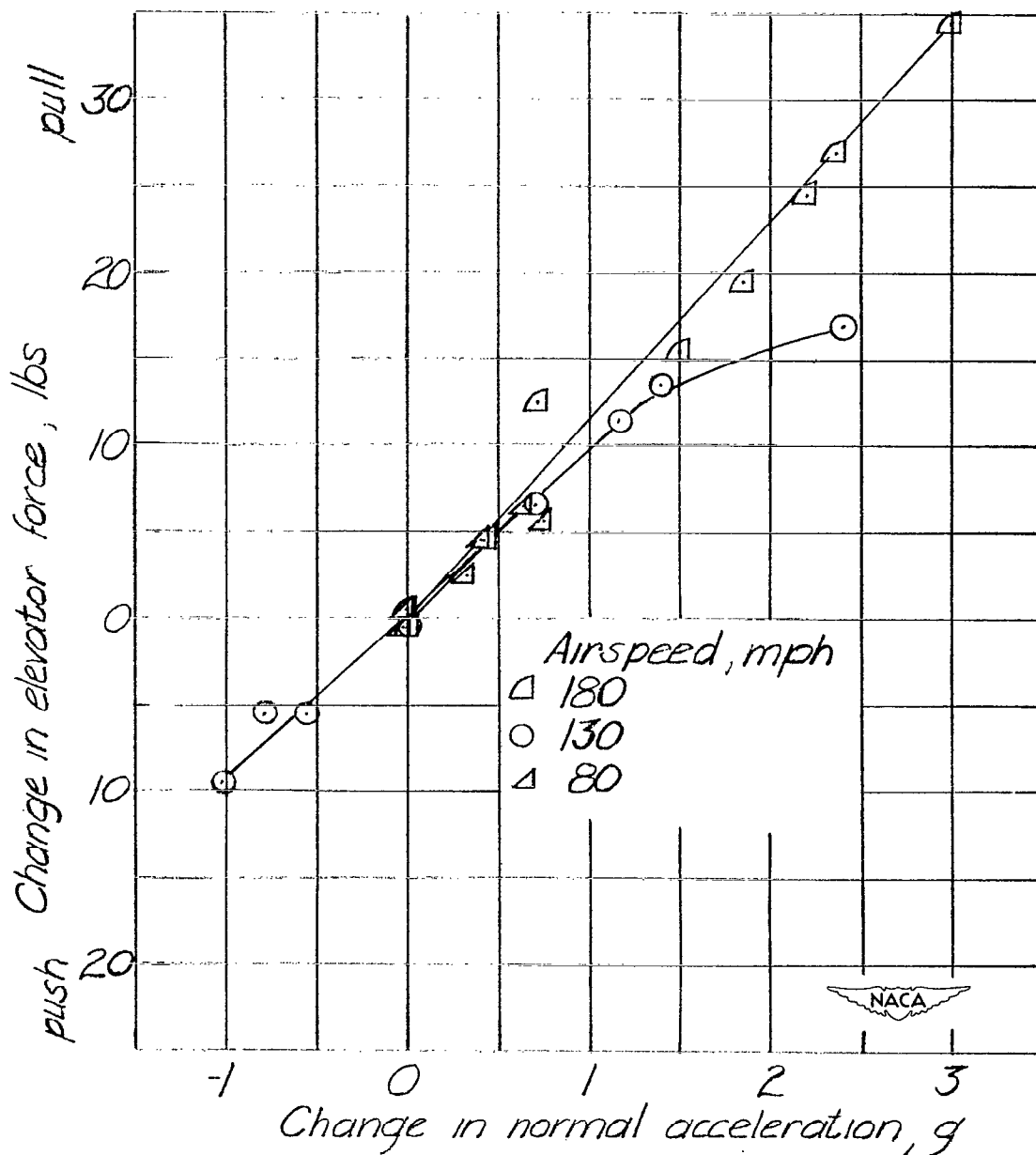
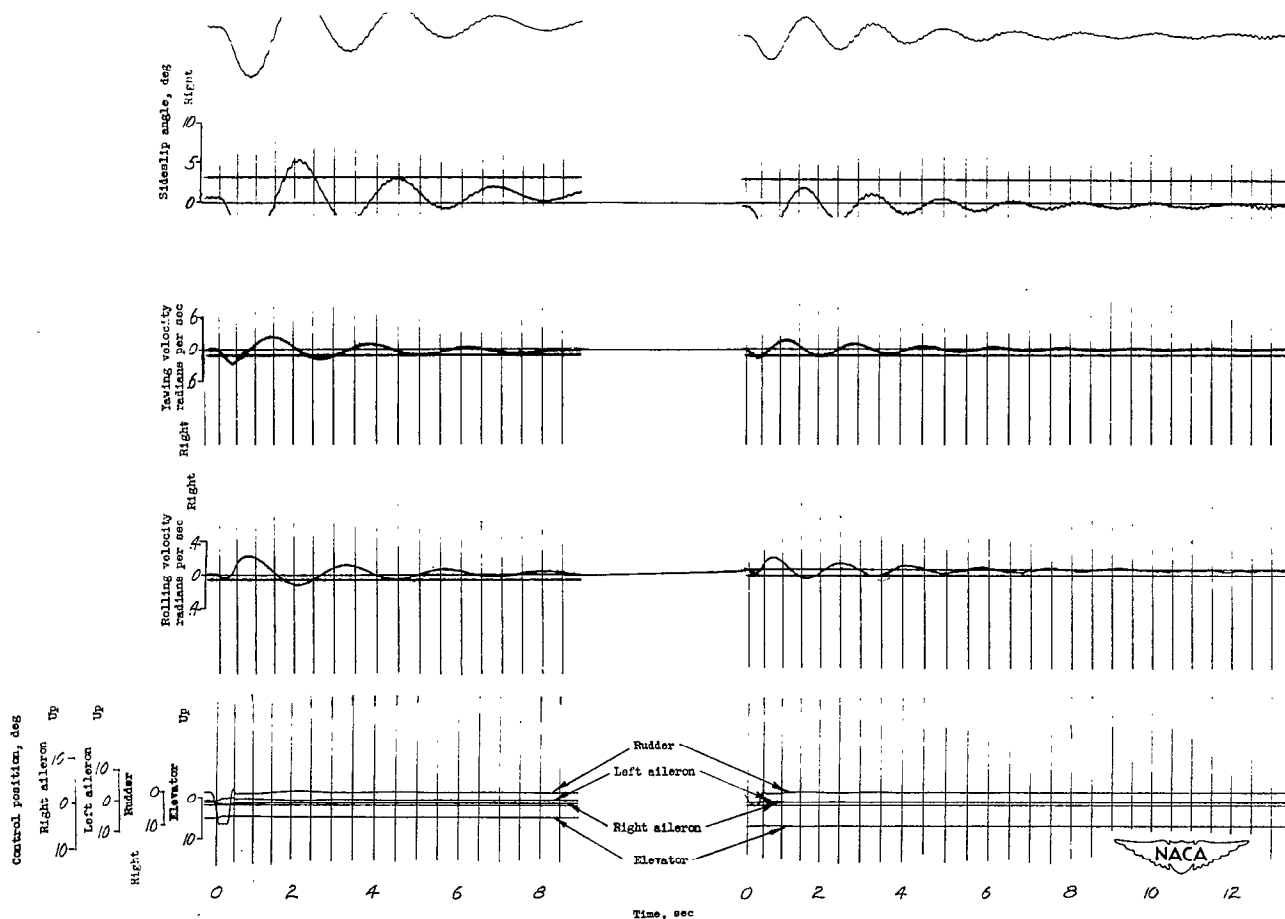


Figure 11.- Variation of elevator force with normal acceleration in steady pull-up and push-down maneuvers for three different airspeeds in the power-on clean condition at a center-of-gravity position of 29.3 percent mean aerodynamic chord for the Beech B-35 Bonanza airplane.



(a) 130 miles per hour.

(b) 160 miles per hour.

Figure 12.- Time histories of the control free oscillations following a rudder kick in the Beech B-35 Bonanza airplane. Airplane in the power-on, clean condition. Center of gravity located at 26.1 percent mean aerodynamic chord.

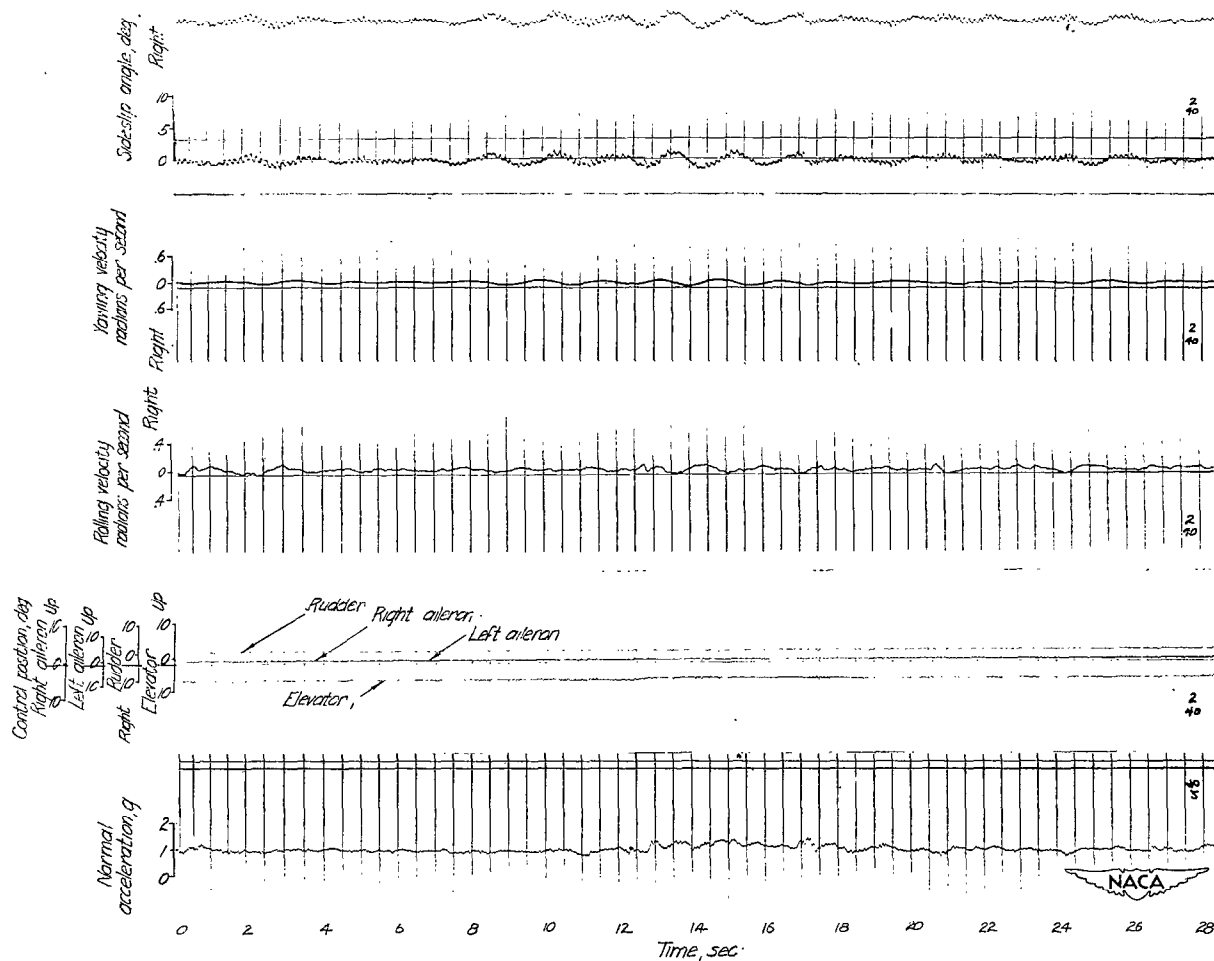
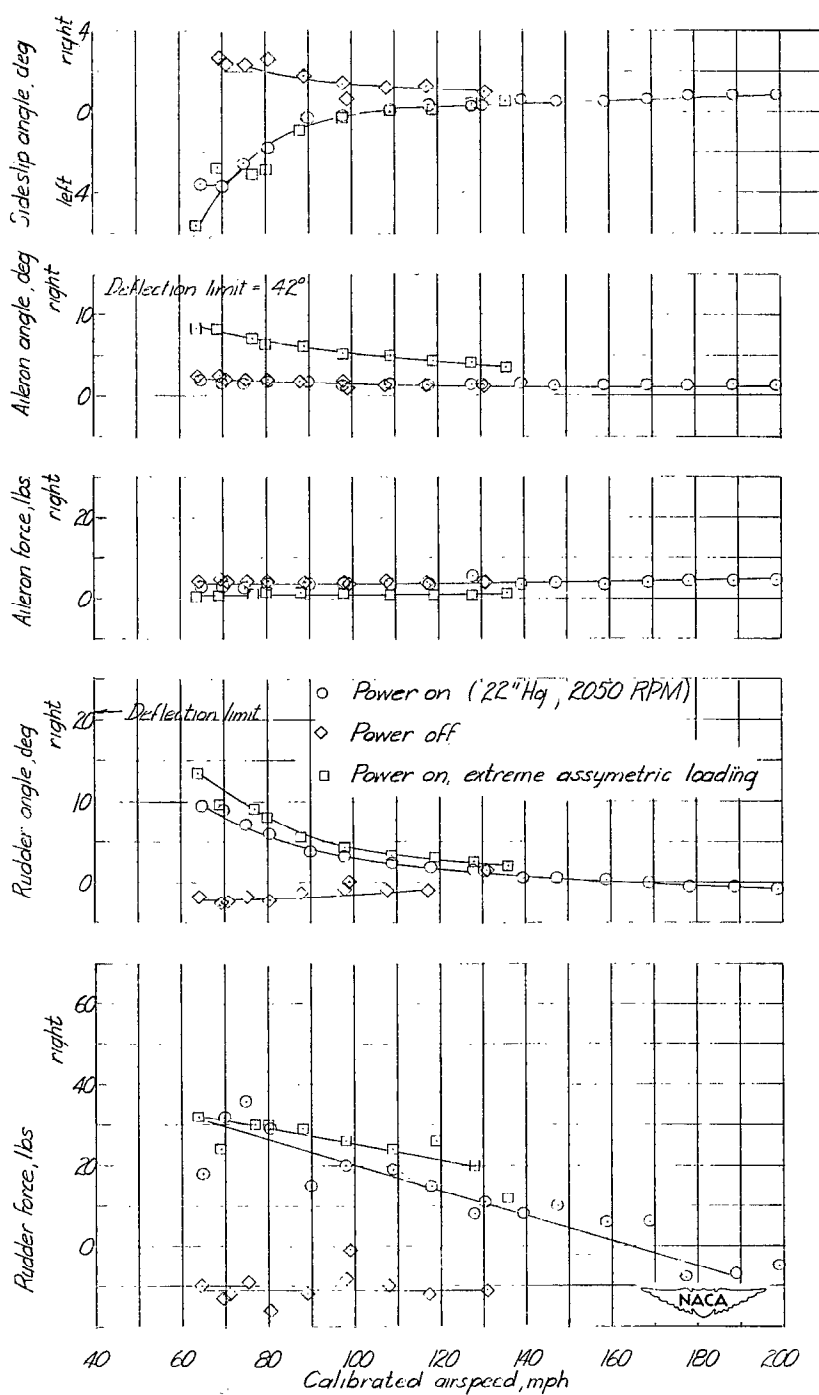
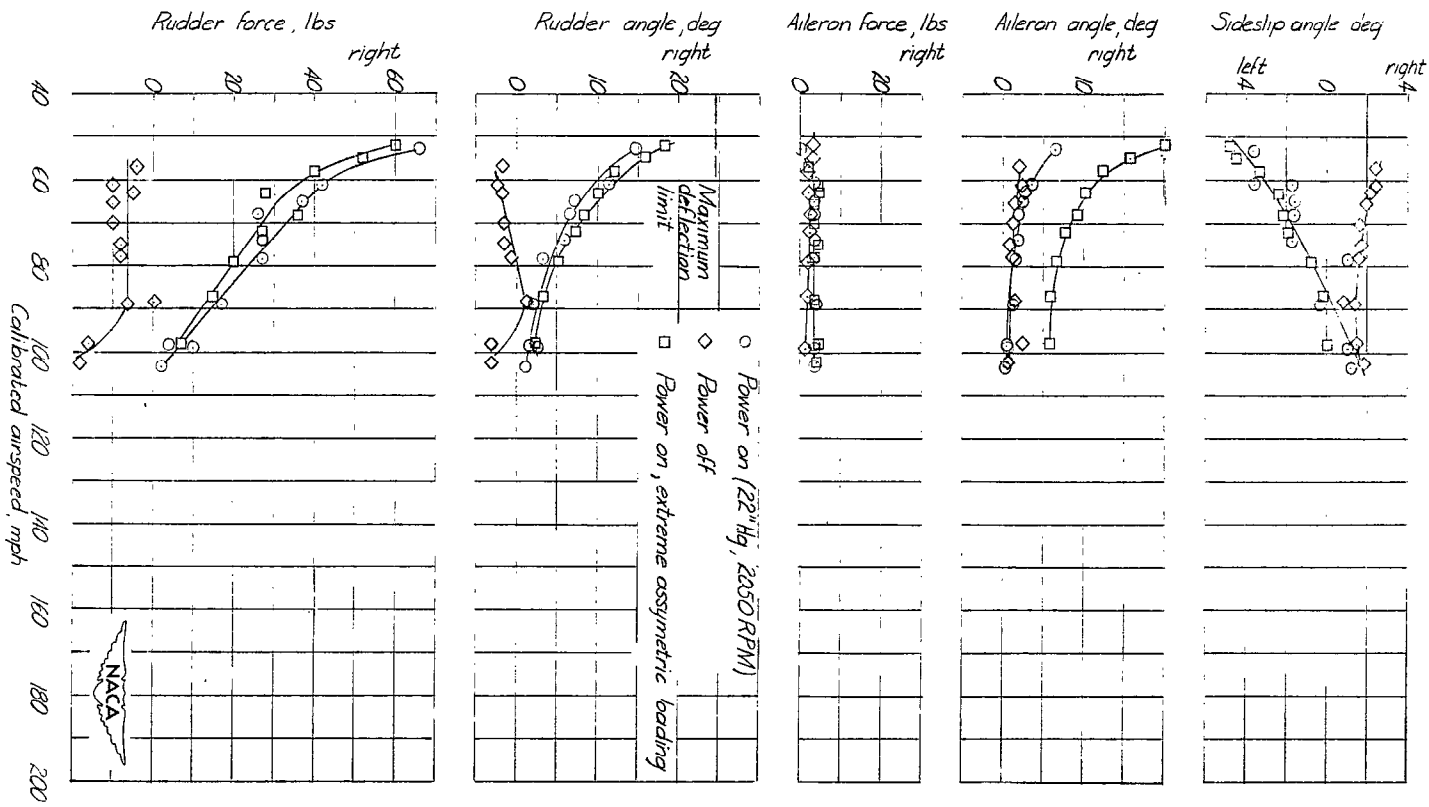


Figure 13.- Example of the lateral oscillations encountered with the Beech B-35 Bonanza airplane in rough air. Airspeed = 140 miles per hour.



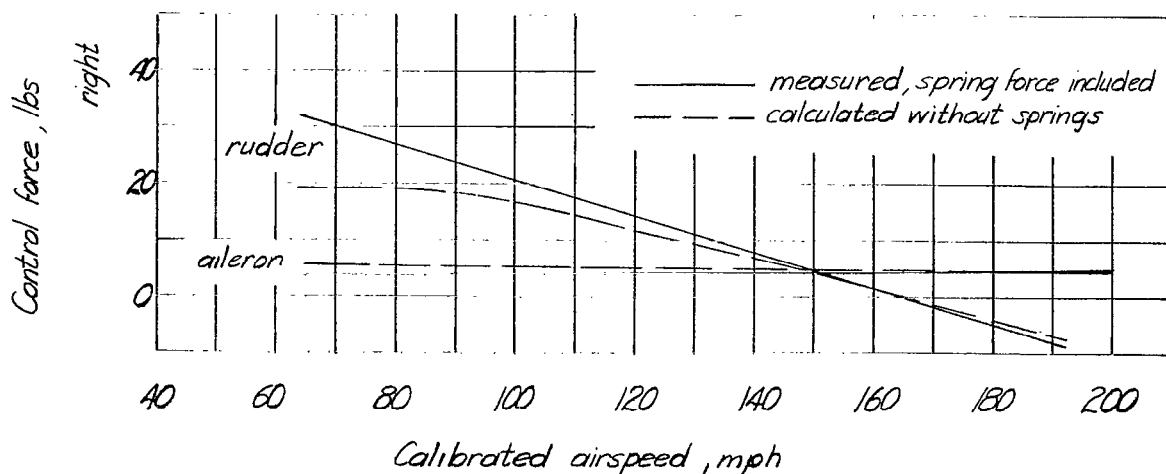
(a) Clean condition.

Figure 14.- Variation of rudder and aileron position and force with airspeed for the Beech B-35 Bonanza airplane.

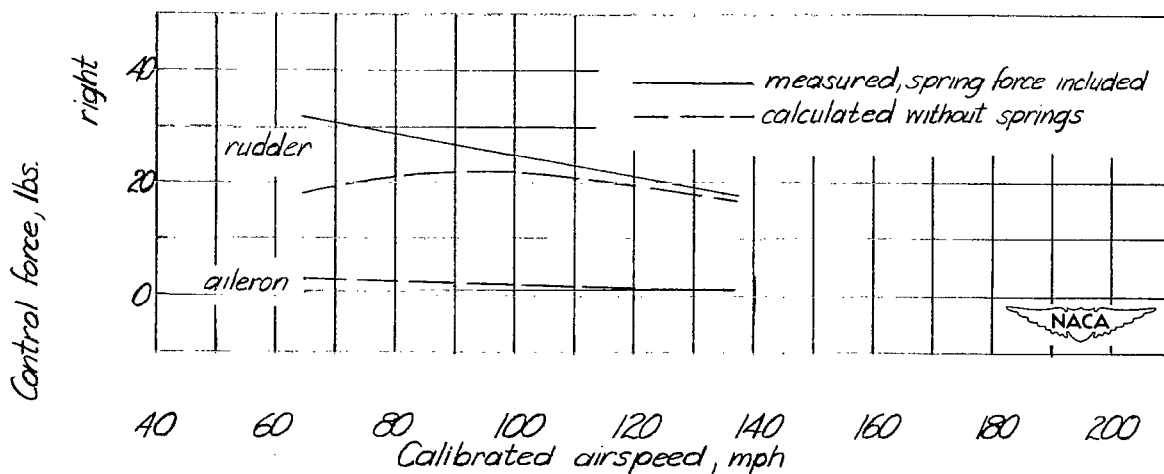


(b) Flaps and gear down.

Figure 14.- Concluded.

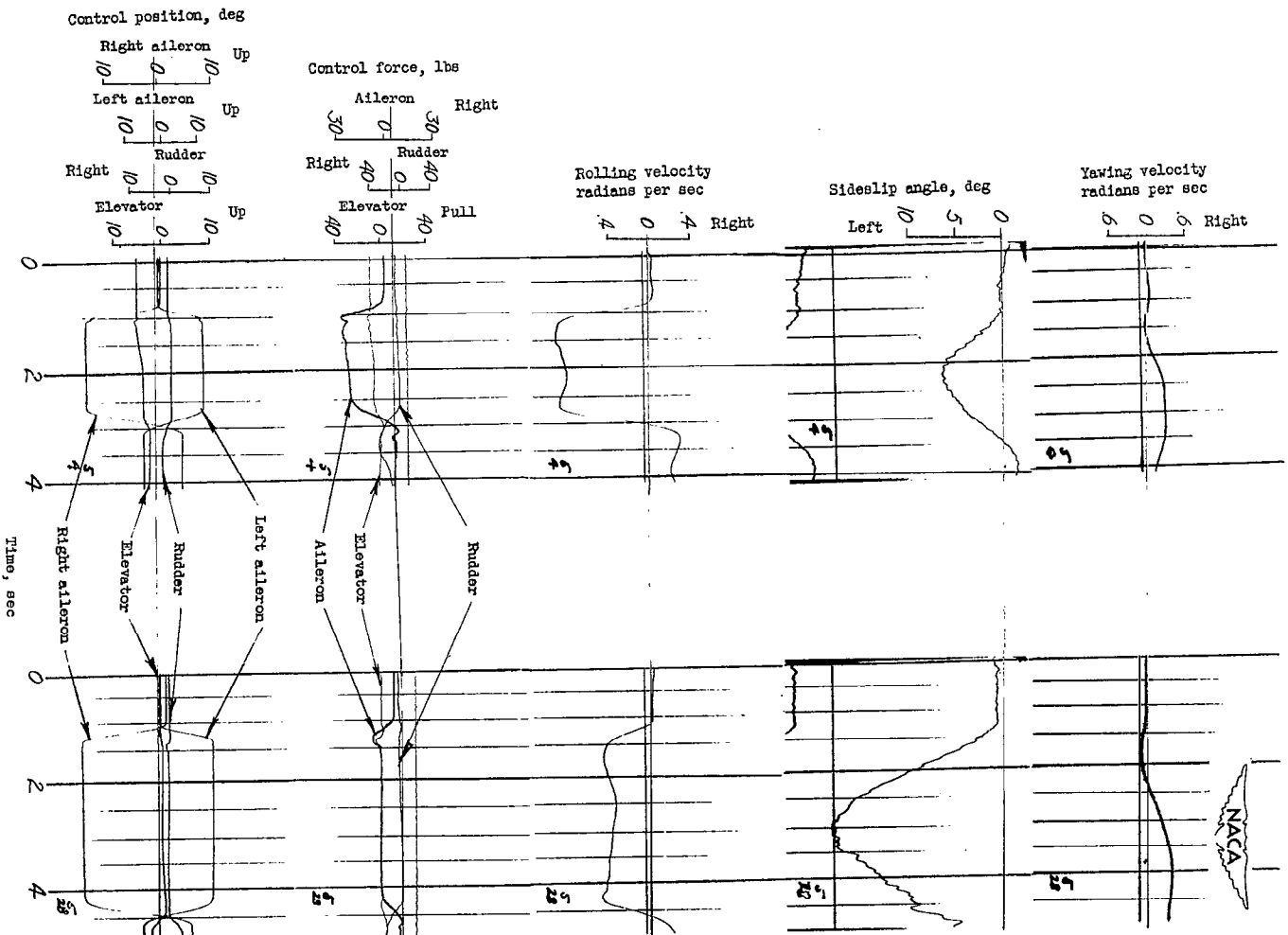


(a) Power on, clean condition.

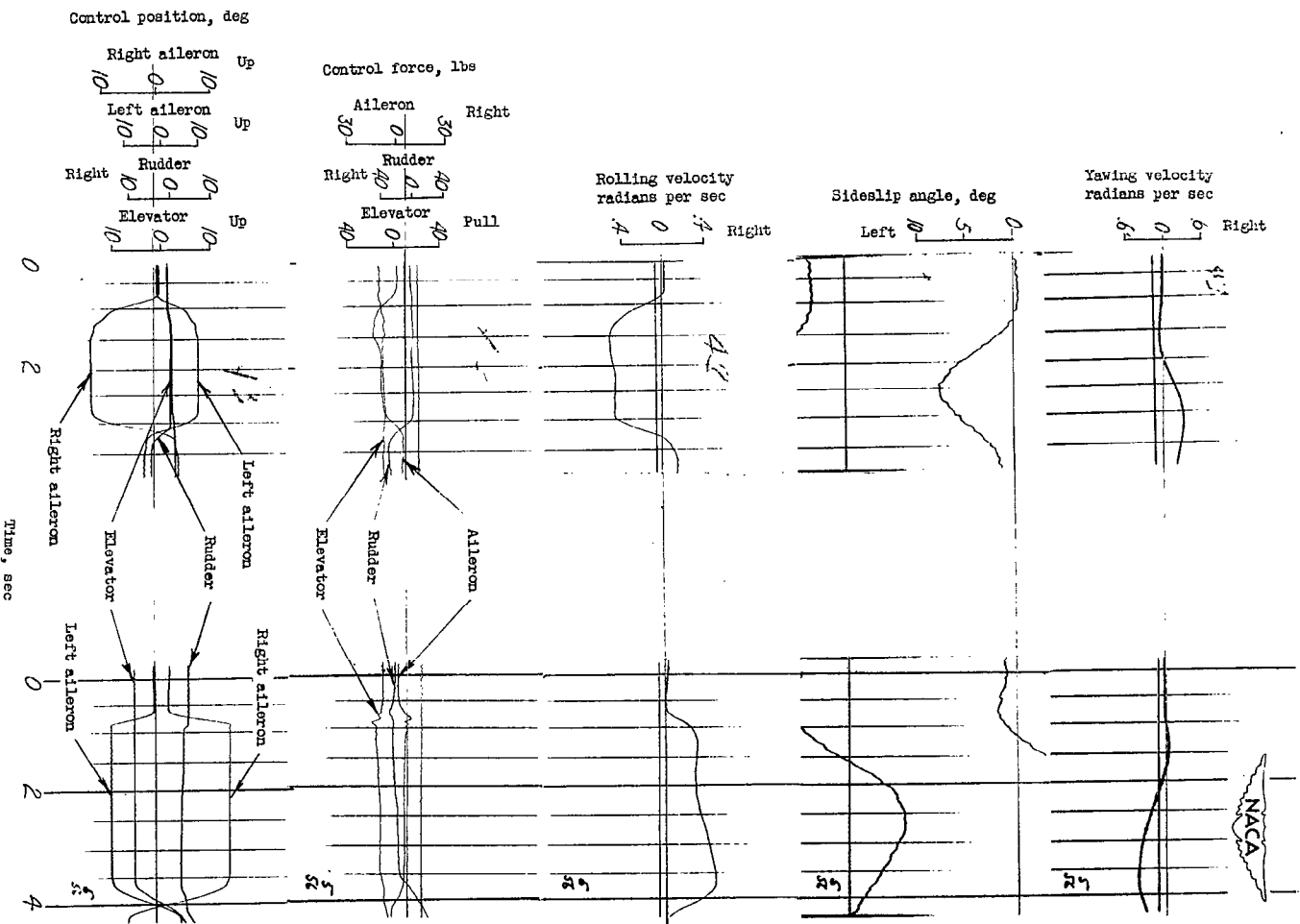


(b) Power on, clean, extreme asymmetric loading.

Figure 15.- The effect of the aileron-rudder coupling springs on the rudder and aileron force variation with airspeed for the Beech B-35 Bonanza airplane.

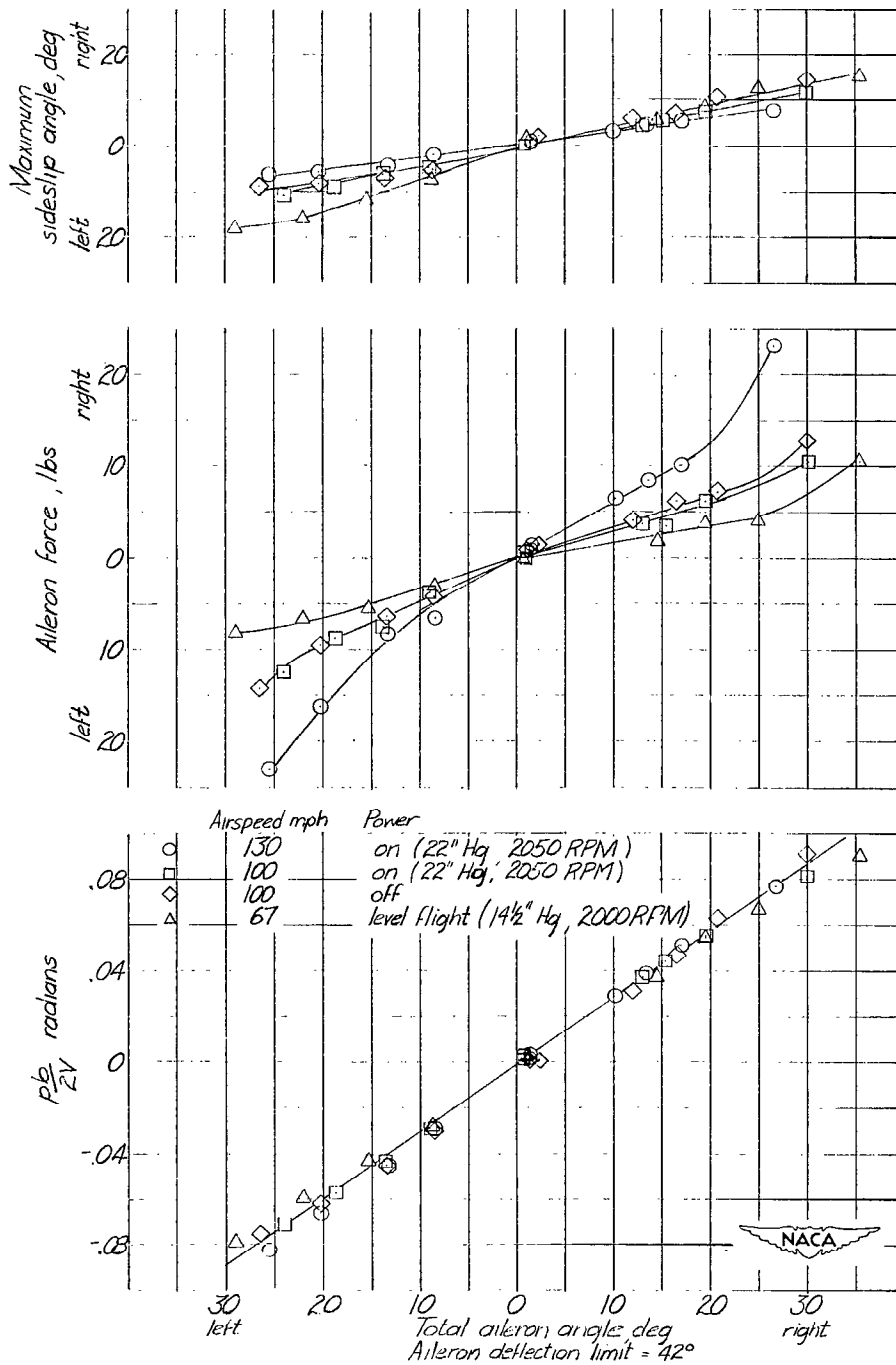


(a) 130 miles per hour; power on; (b) 67 miles per hour; power for level flight; clean.
 Figure 16.- Time histories of rudder-fixed aileron rolls in the Beech B-35 Bonanza airplane.



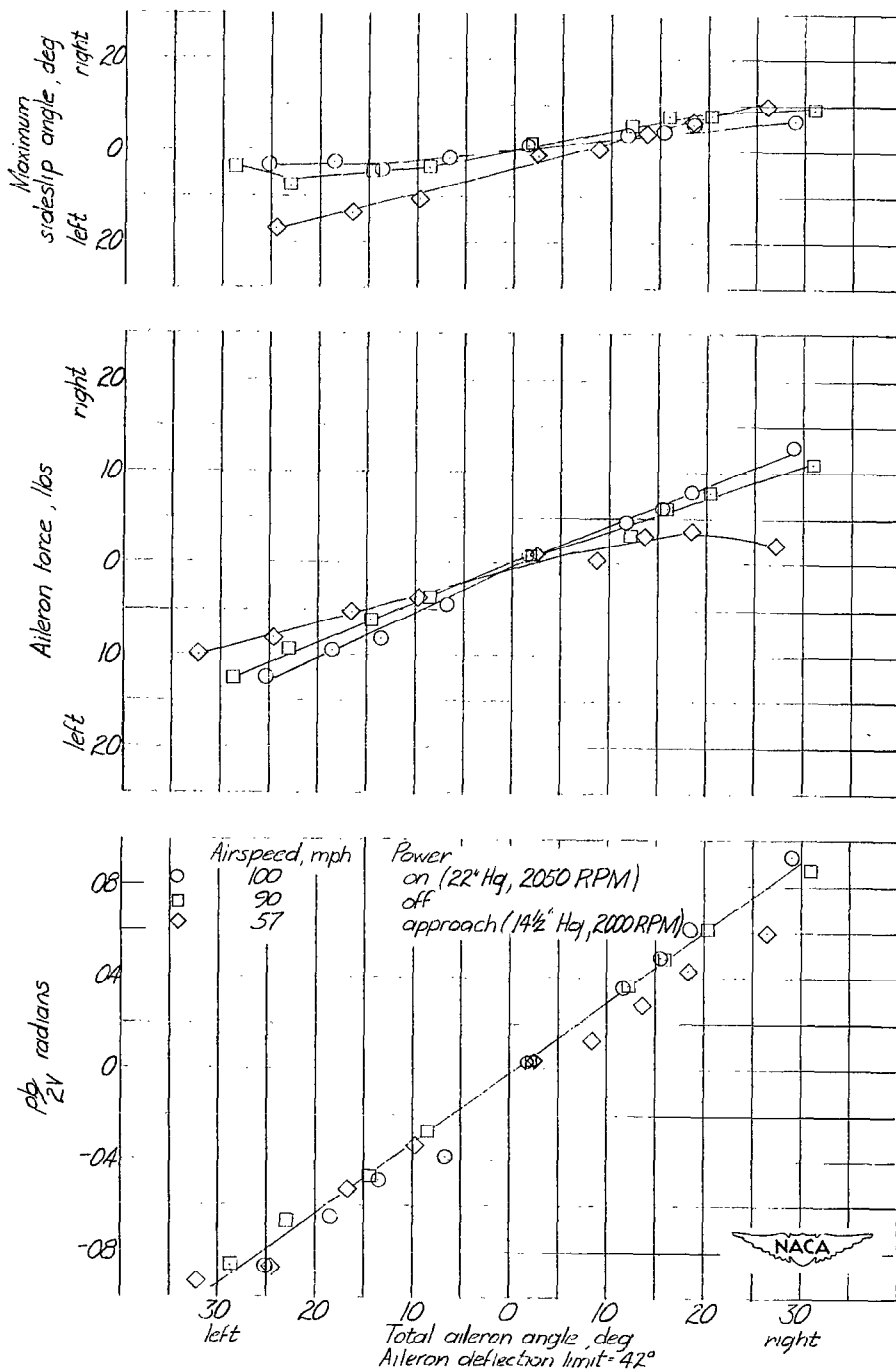
(c) 90 miles per hour; power off; flaps down. (d) 57 miles per hour; power for approach; flaps down.

Figure 16.- Concluded.



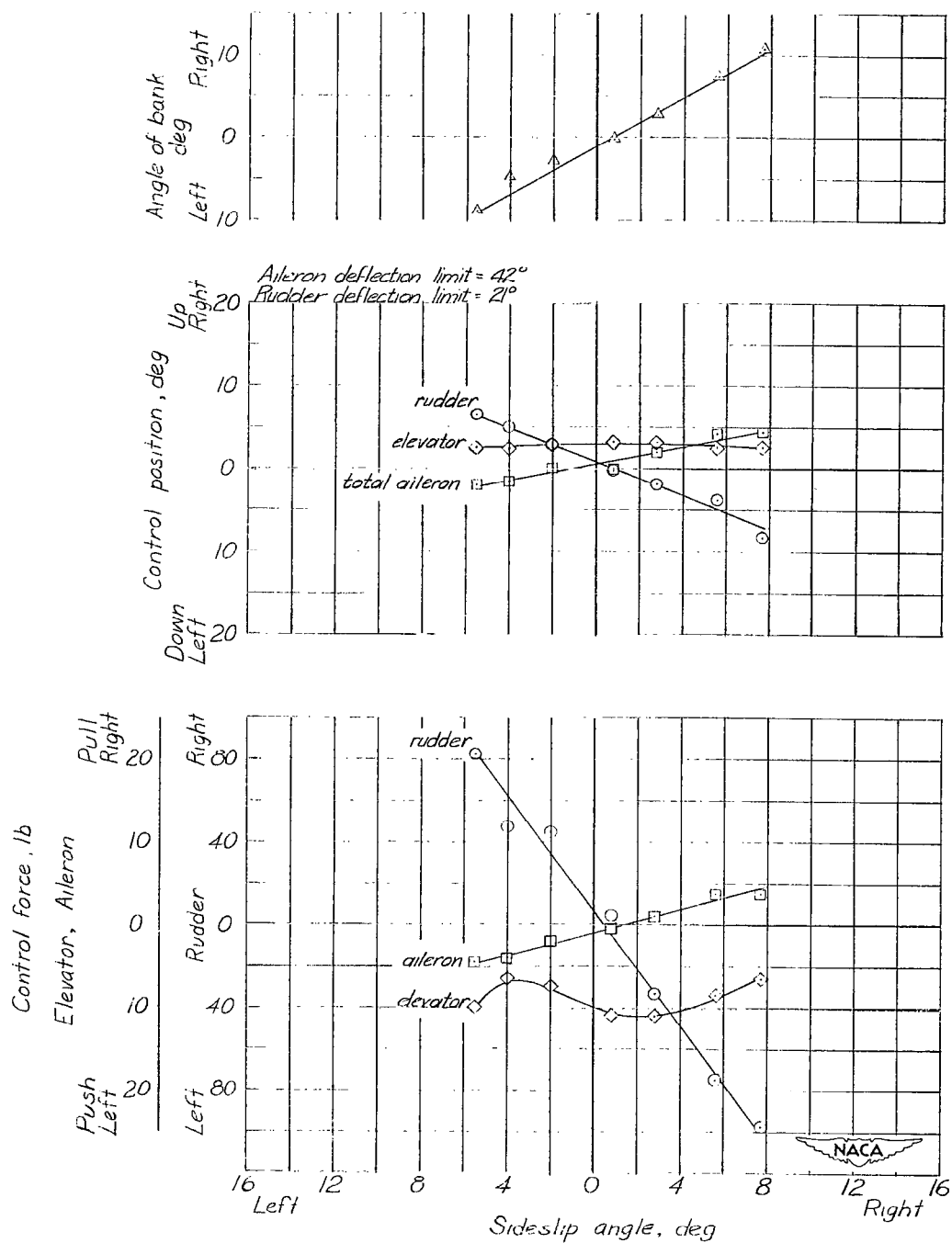
(a) Clean conditions.

Figure 17.- Variation of helix angle $\frac{pb}{2V}$; aileron force, and maximum sideslip angle with aileron angle for the rudder-fixed aileron rolls in the Beech B-35 Bonanza airplane.



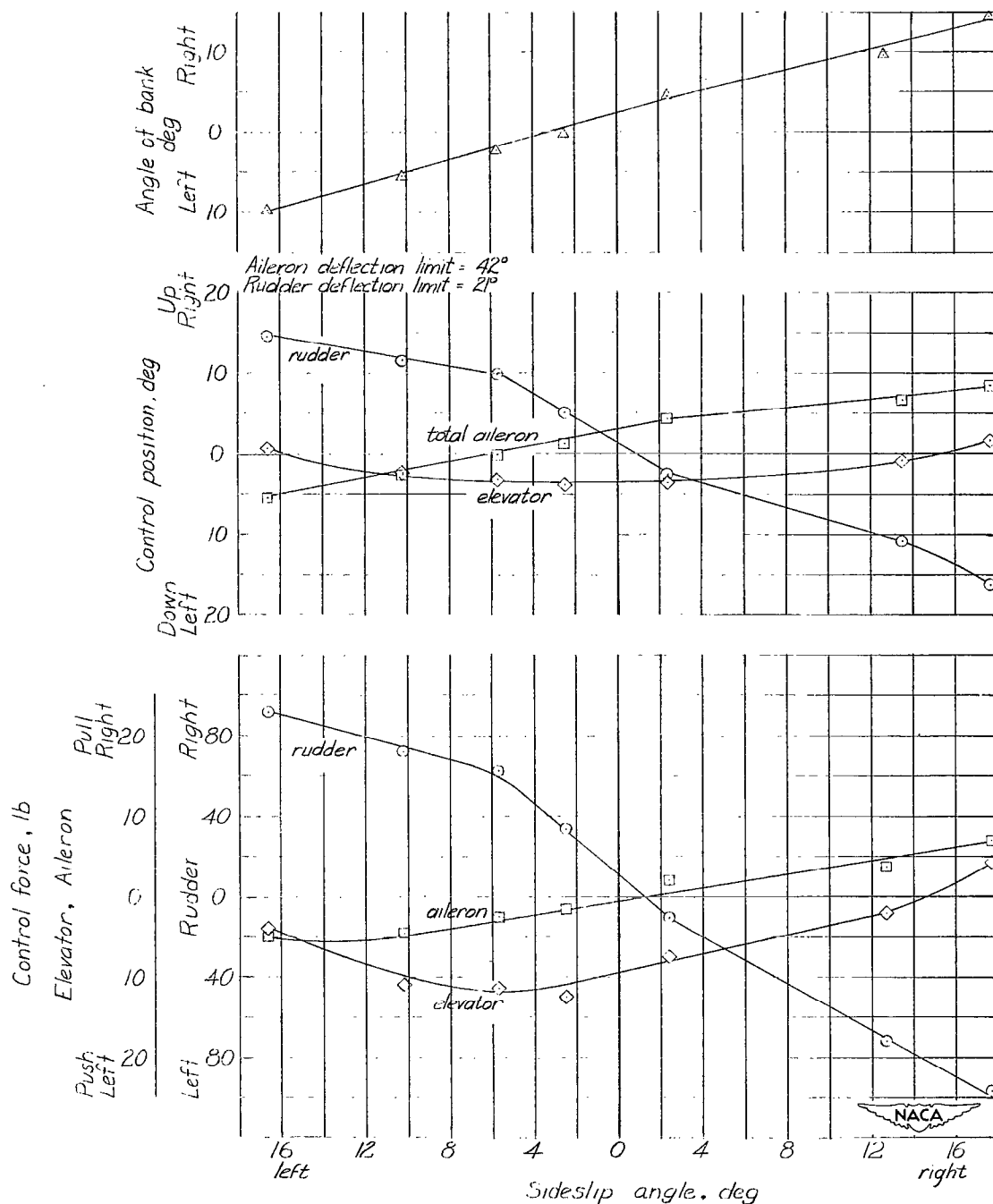
(b) Flaps-down conditions.

Figure 17.- Concluded.



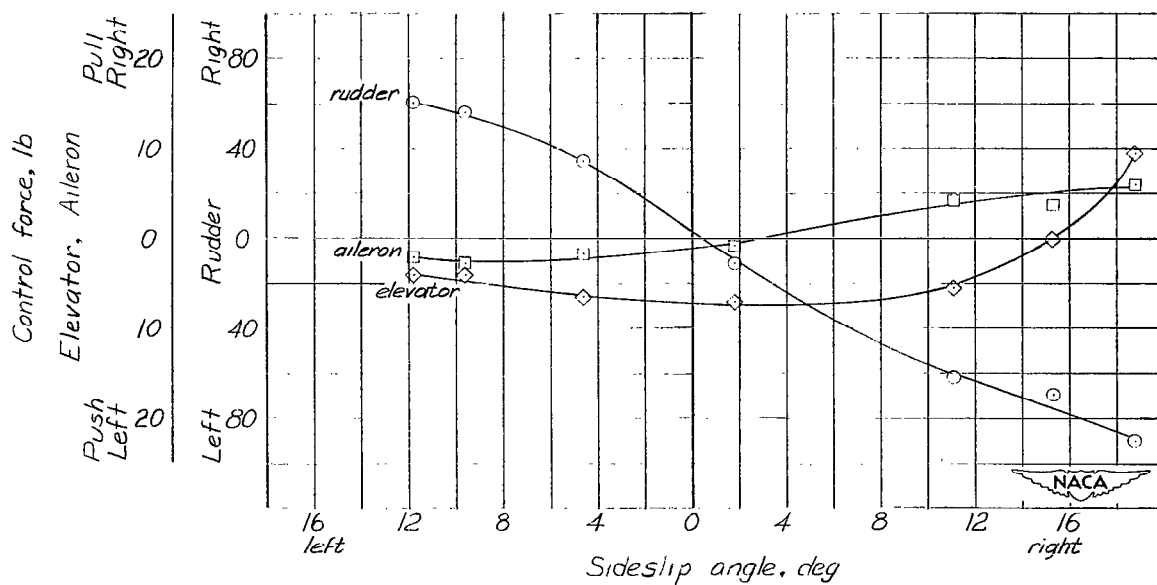
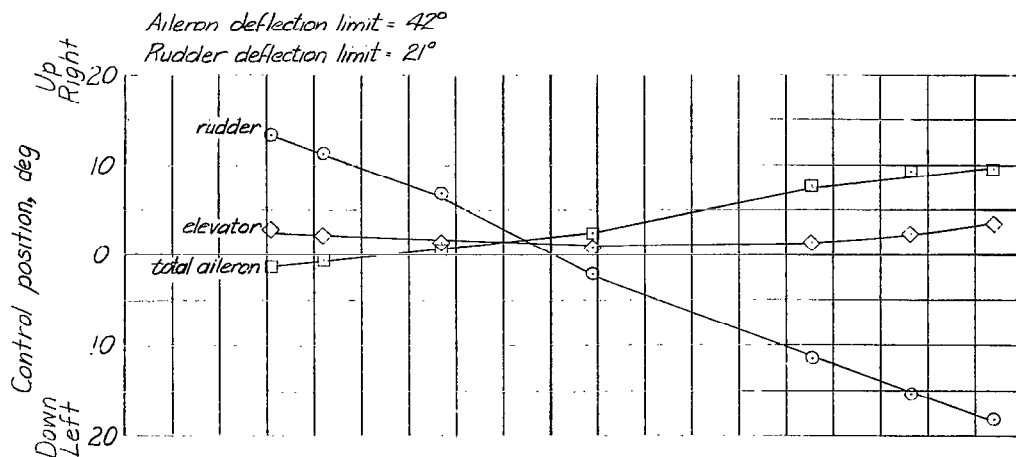
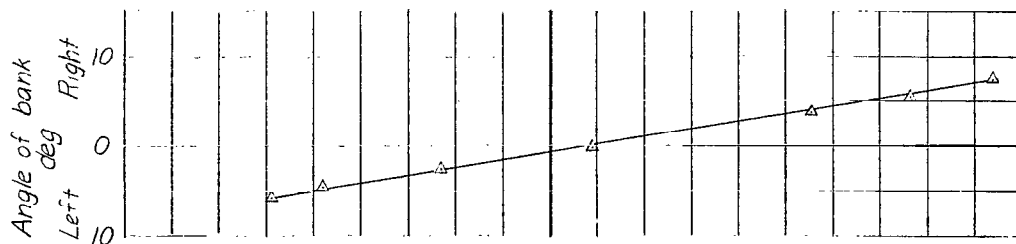
(a) Power on (22 in. Hg at 2050 rpm); clean condition;
airspeed = 160 miles per hour.

Figure 18.- Sideslip characteristics of the Beech B-35 Bonanza airplane.



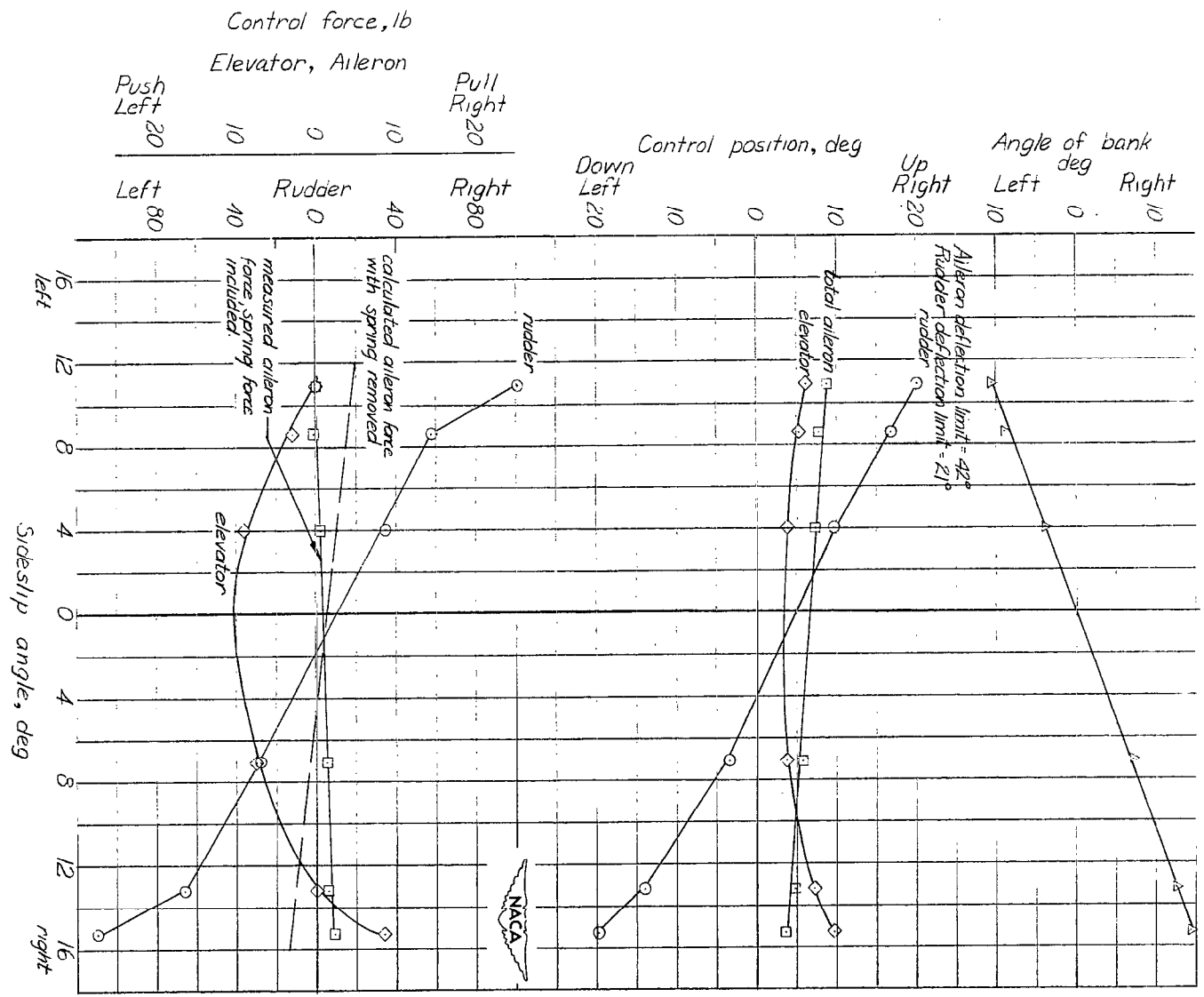
(b) Power on (22 in. Hg at 2050 rpm); clean condition;
 airspeed = 100 miles per hour.

Figure 18.- Continued.



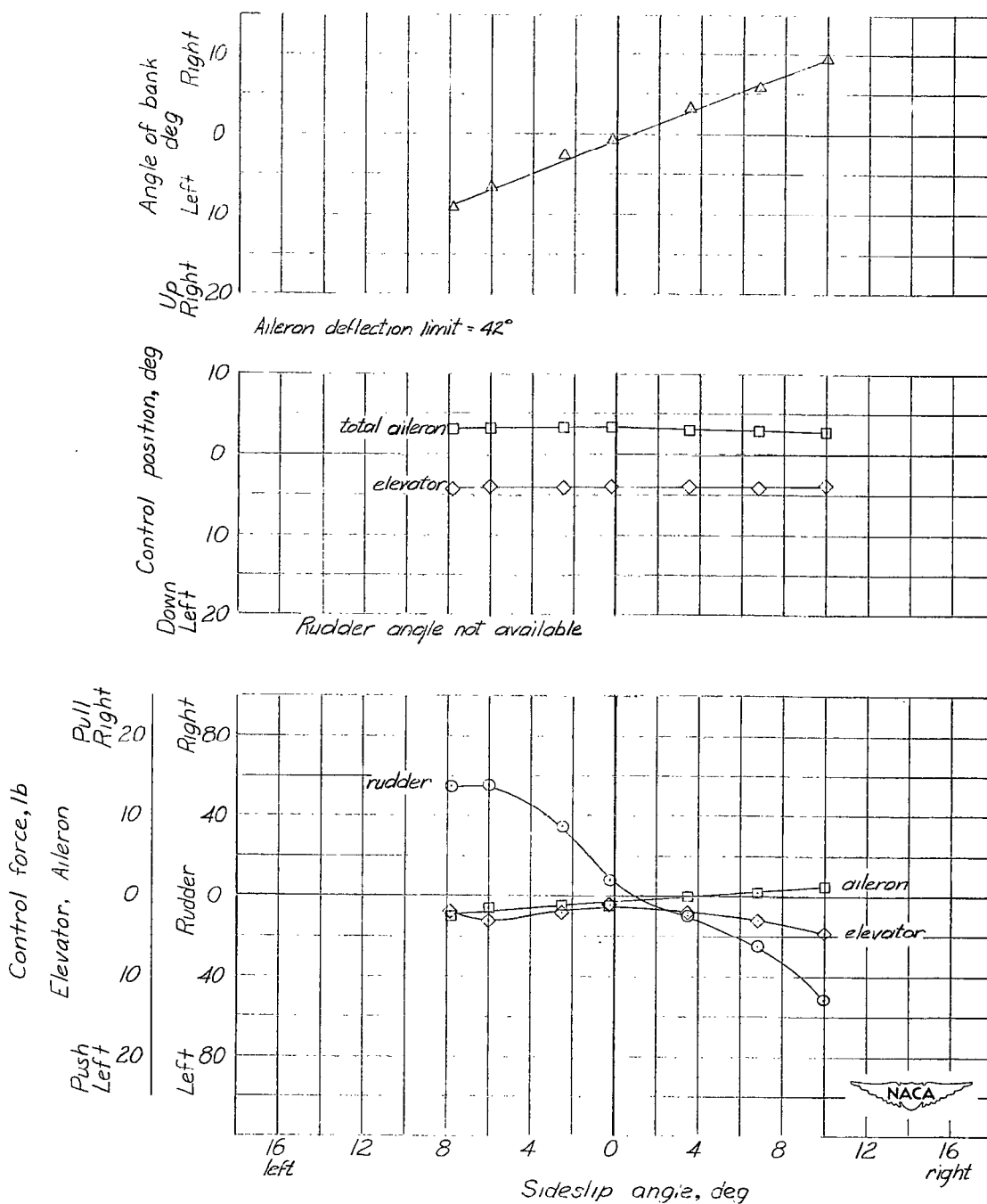
(c) Power off; flaps down; airspeed = 90 miles per hour.

Figure 18.- Continued.



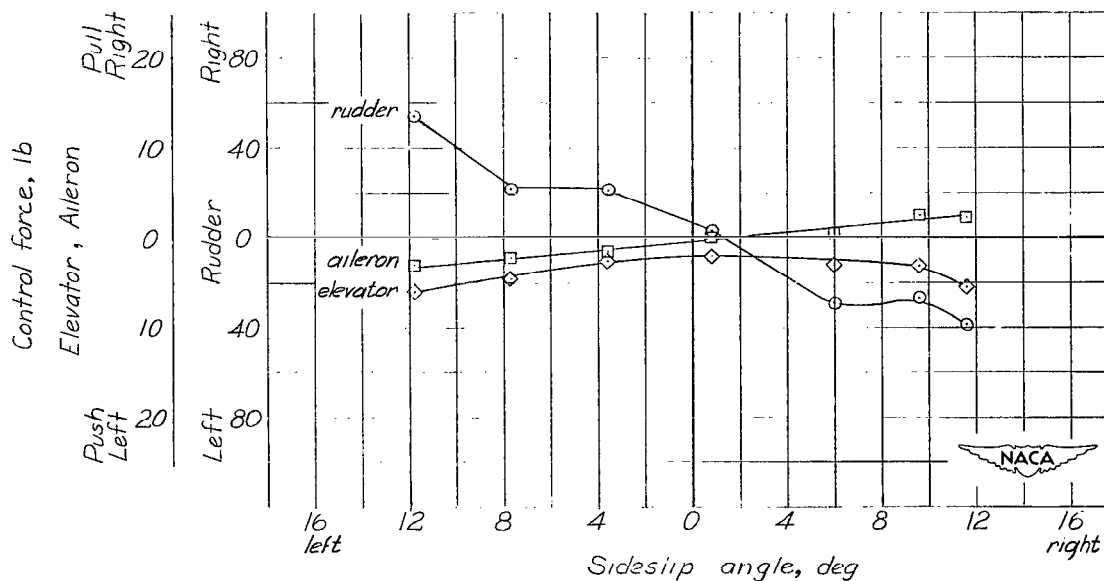
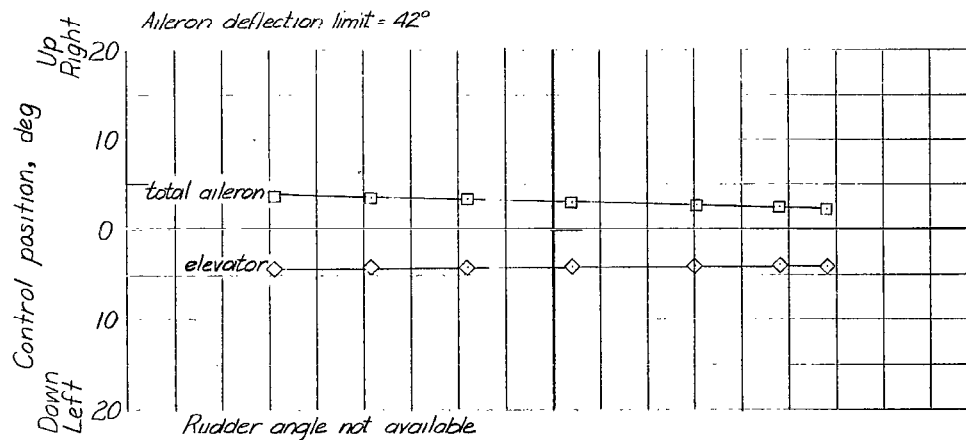
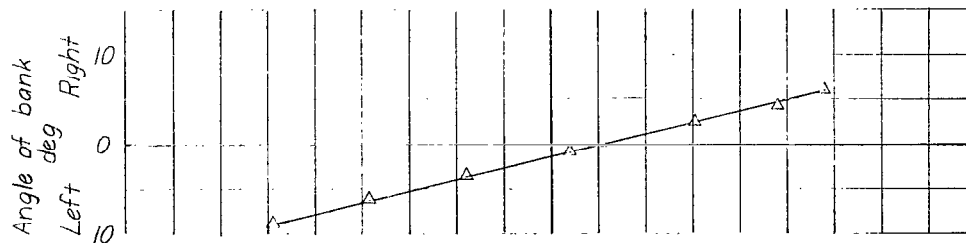
(d) Power for approach ($14\frac{1}{2}$ in. Hg at 2000 rpm); flaps down; airspeed = 77 miles per hour.

Figure 18.- Continued.



(e) Power on (22 in. Hg at 2050 rpm); flaps and gear down; airspeed = 100 miles per hour.

Figure 18.- Continued.



(f) Power off; flaps and gear down; airspeed = 90 miles per hour.

Figure 18.- Concluded.

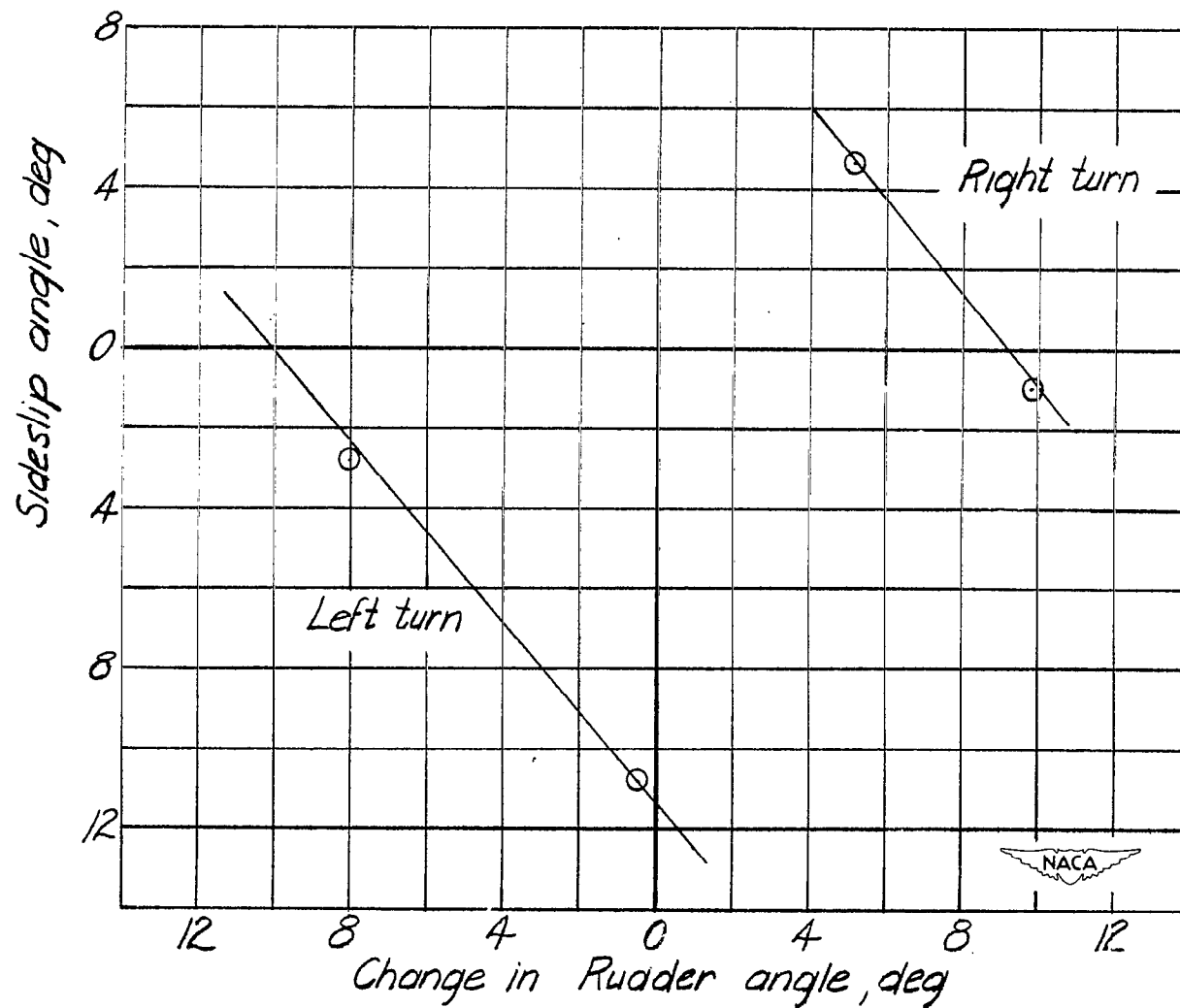
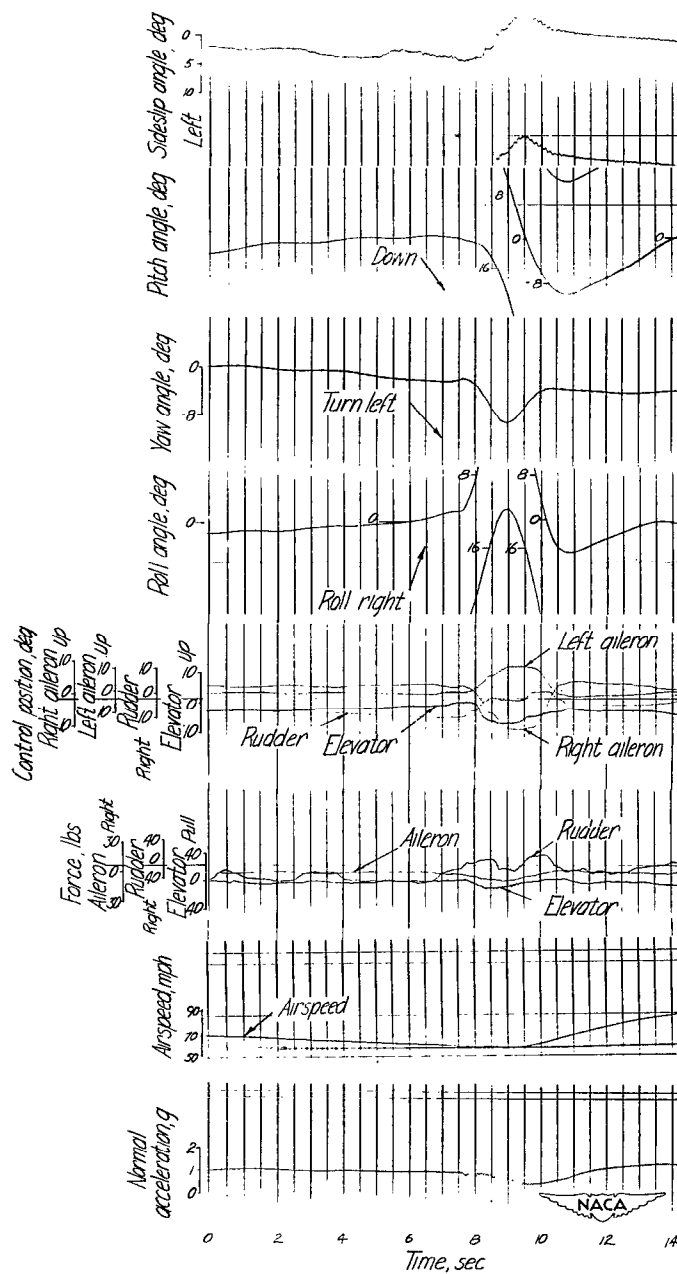
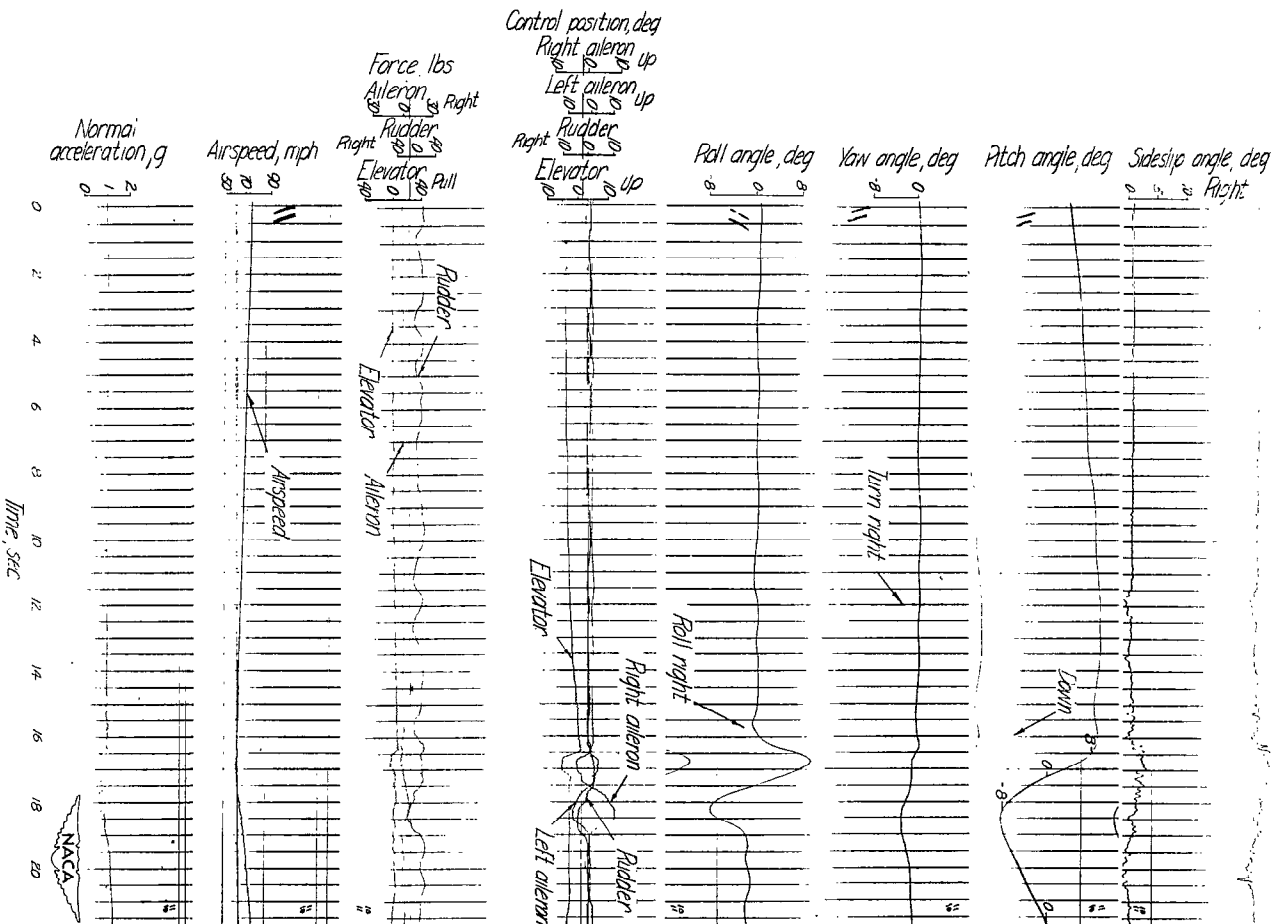


Figure 19.- Plot of maximum sideslip reached in one-half aileron rolls made with varying amounts of rudder angle at 66 miles per hour, power on, clean condition. Beech B-35 Bonanza airplane.



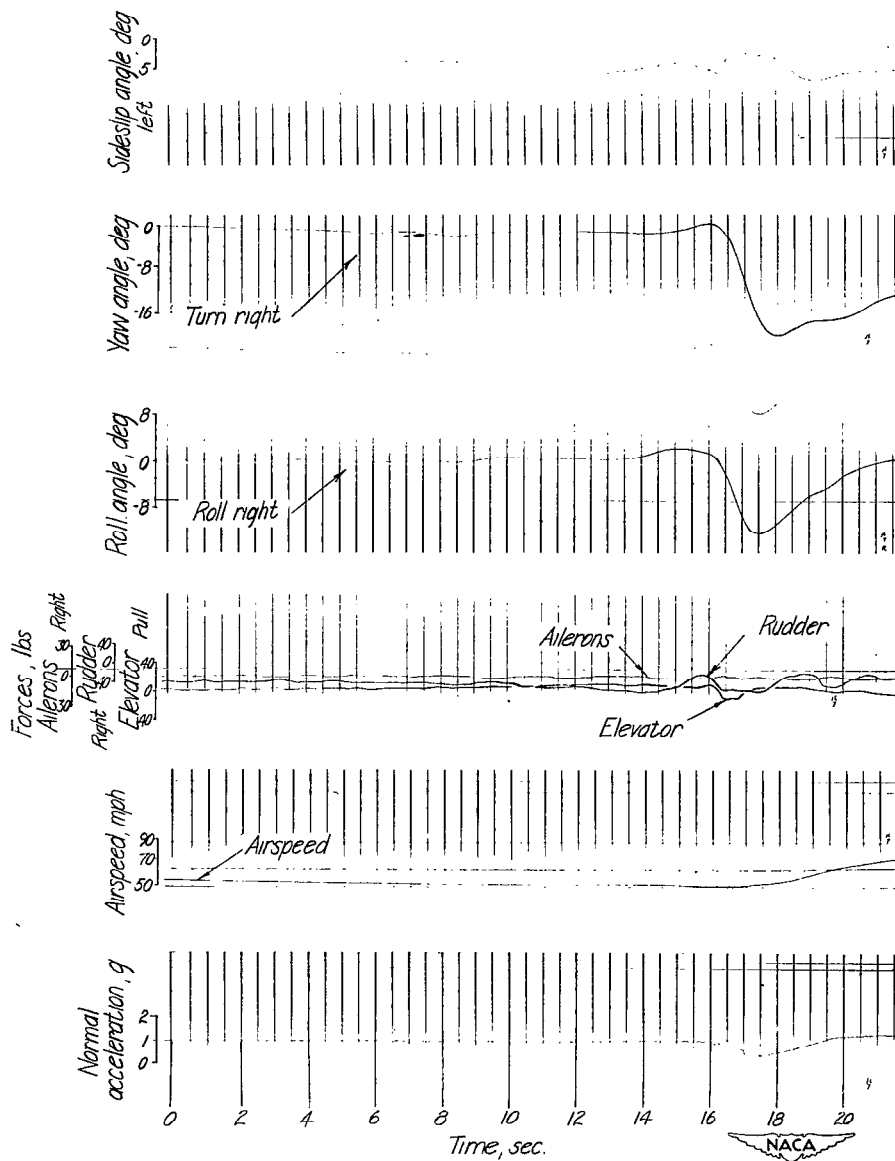
(a) Power on (22 in. Hg at 2050 rpm); normal recovery; clean condition.

Figure 20.- Time histories of stalls in the Beech B-35 Bonanza airplane.
Center of gravity = 29.3 percent mean aerodynamic chord;
weight = 2500 pounds.



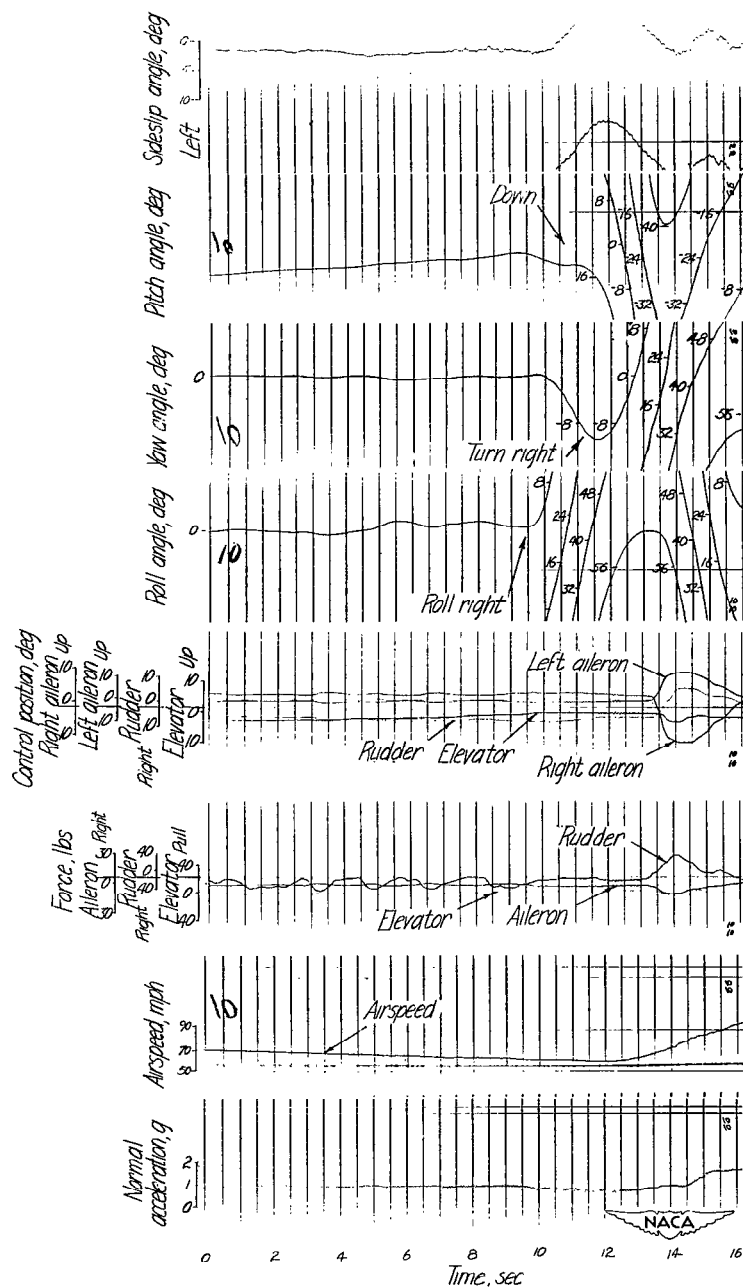
(b) Power off; clean condition; normal recovery.

Figure 20.- Continued.



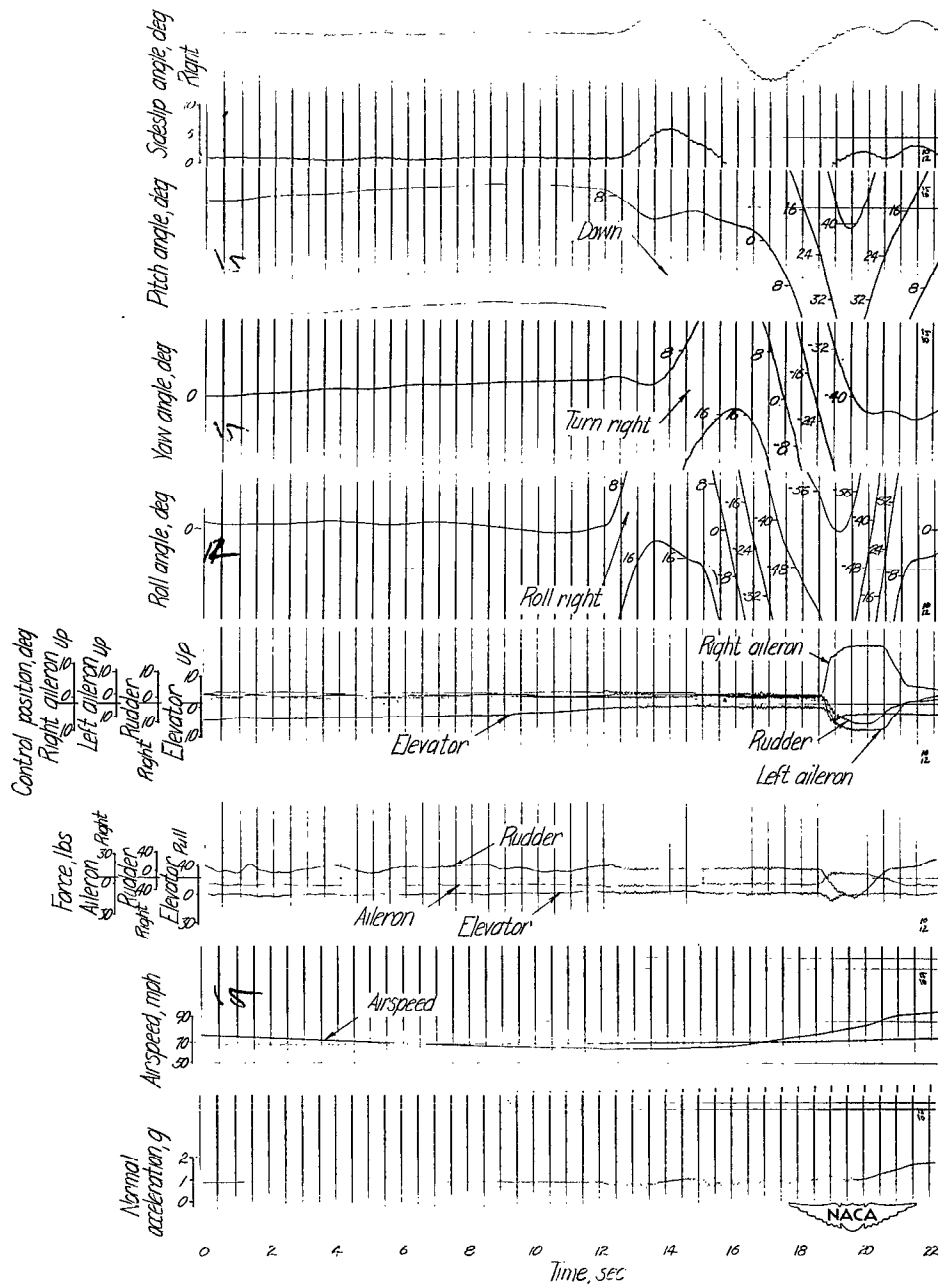
(c) Power on; landing condition; normal recovery.

Figure 20.- Continued.



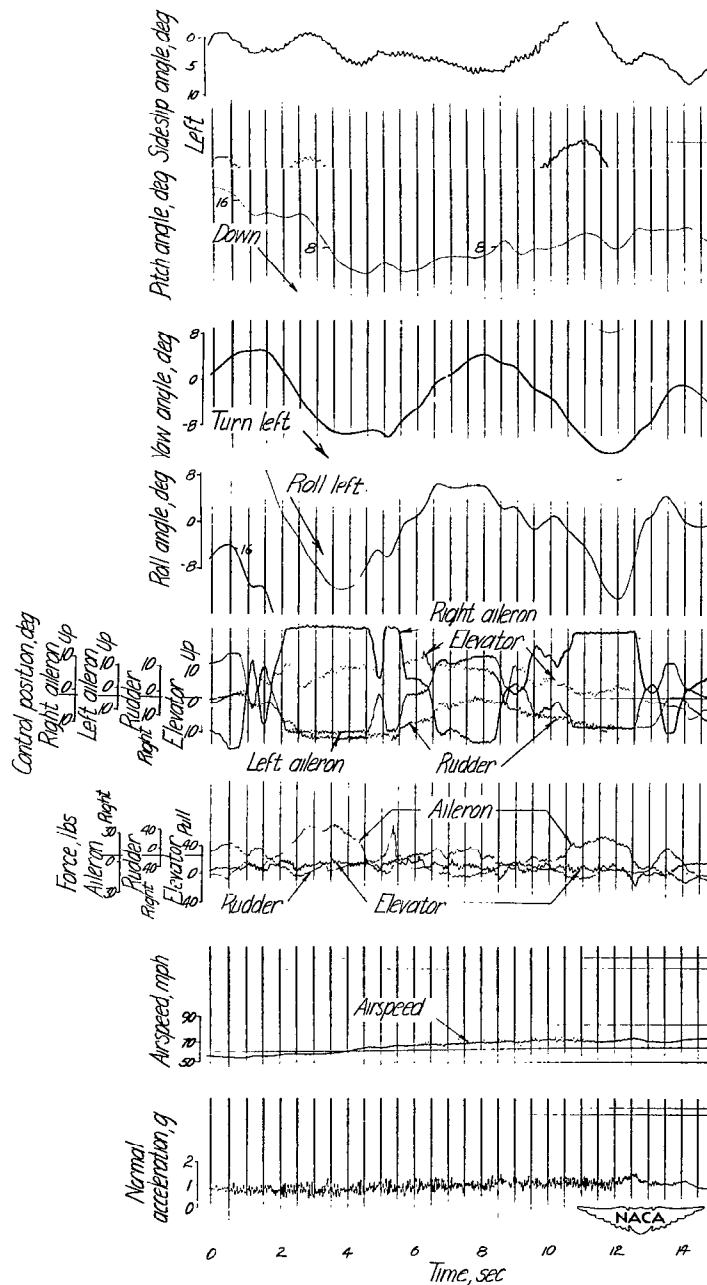
(d) Power on; clean condition; controls held fixed.

Figure 20.- Continued.



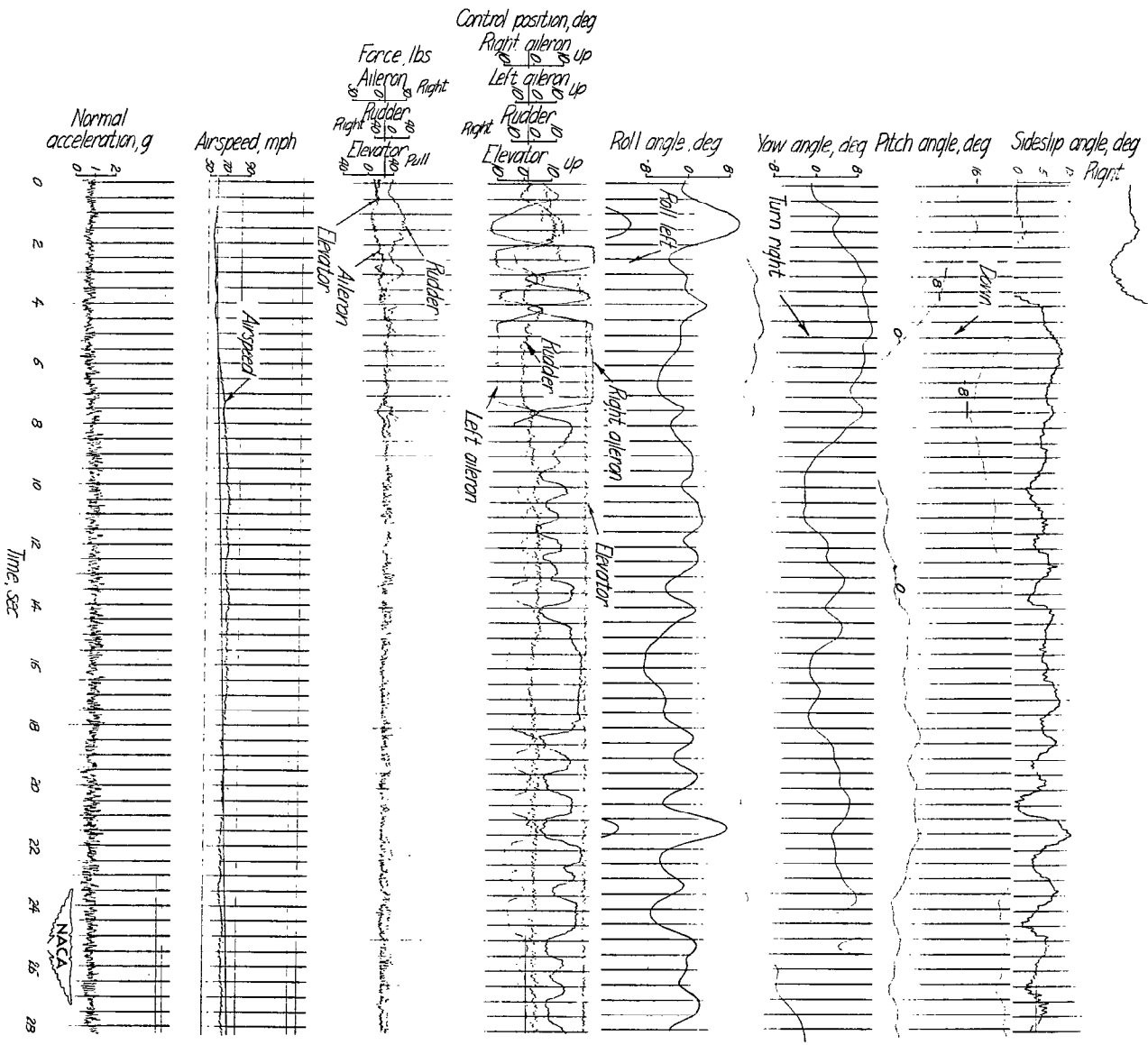
(e) Power off; clean condition; controls held fixed.

Figure 20.- Continued.



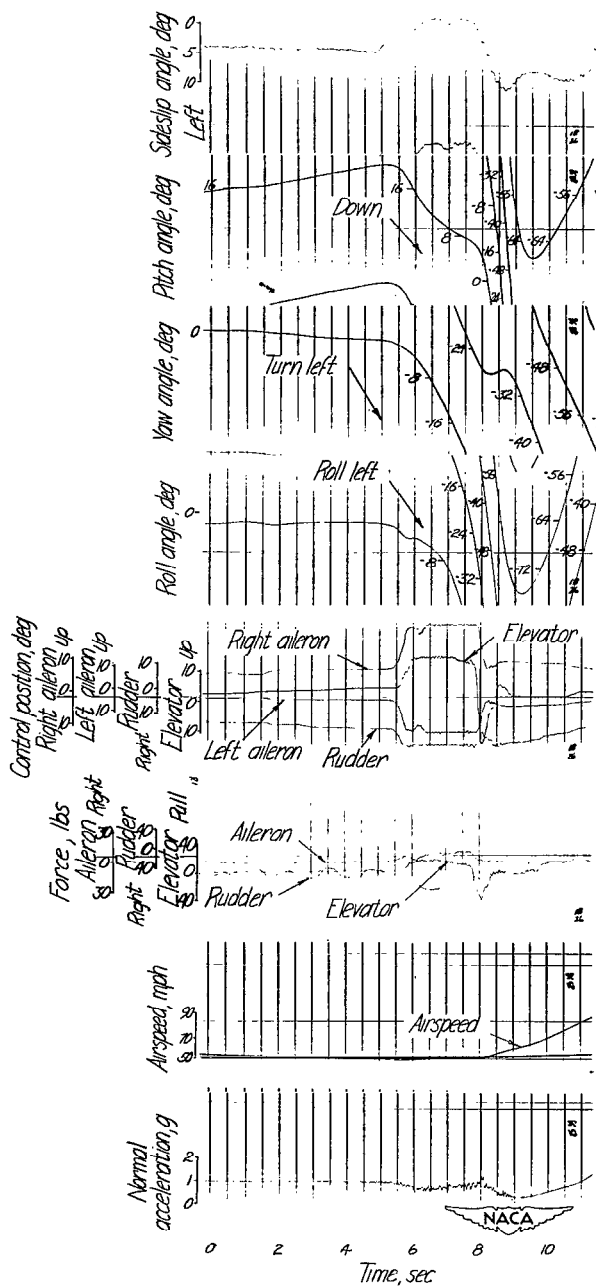
(f) Power on; clean condition; airplane controlled beyond the stall.

Figure 20.- Continued.



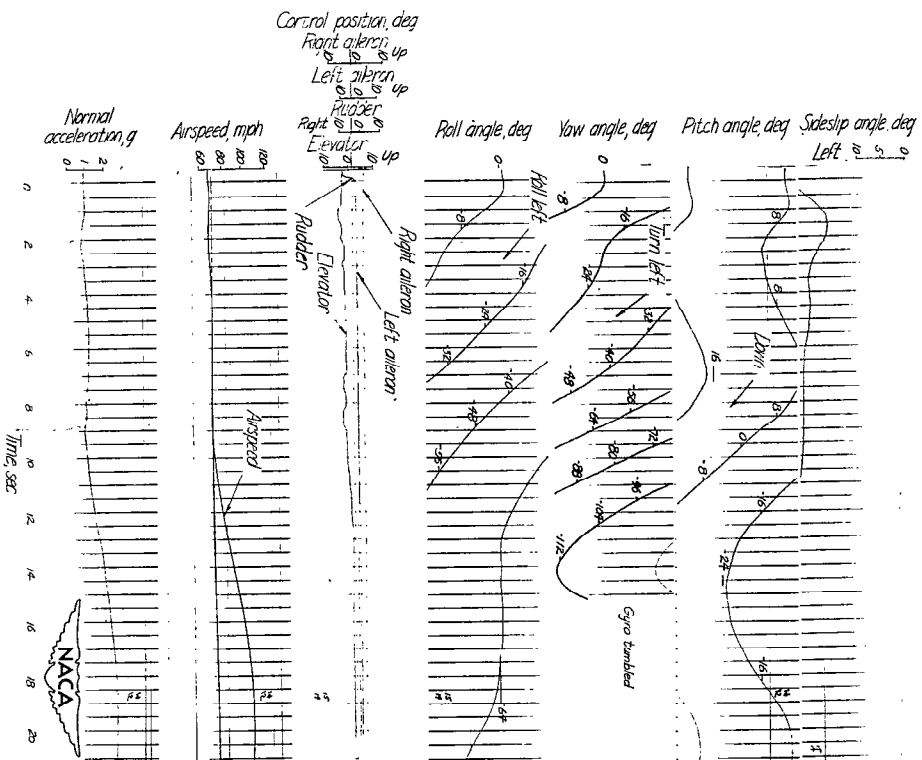
(g) Power off; clean condition; airplane controlled beyond the stall.

Figure 20.- Continued.



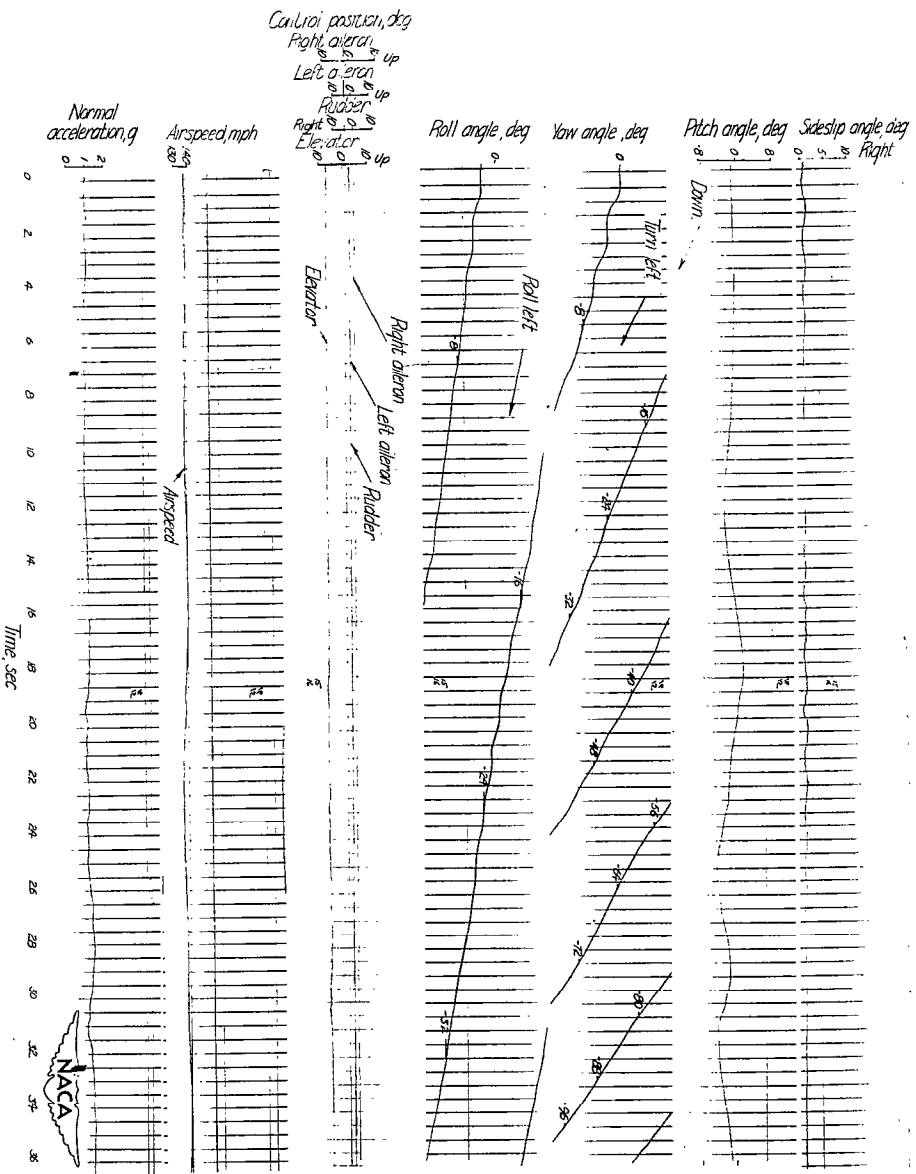
(h) Power on; landing condition; attempt to control the airplane beyond the stall.

Figure 20.- Concluded.



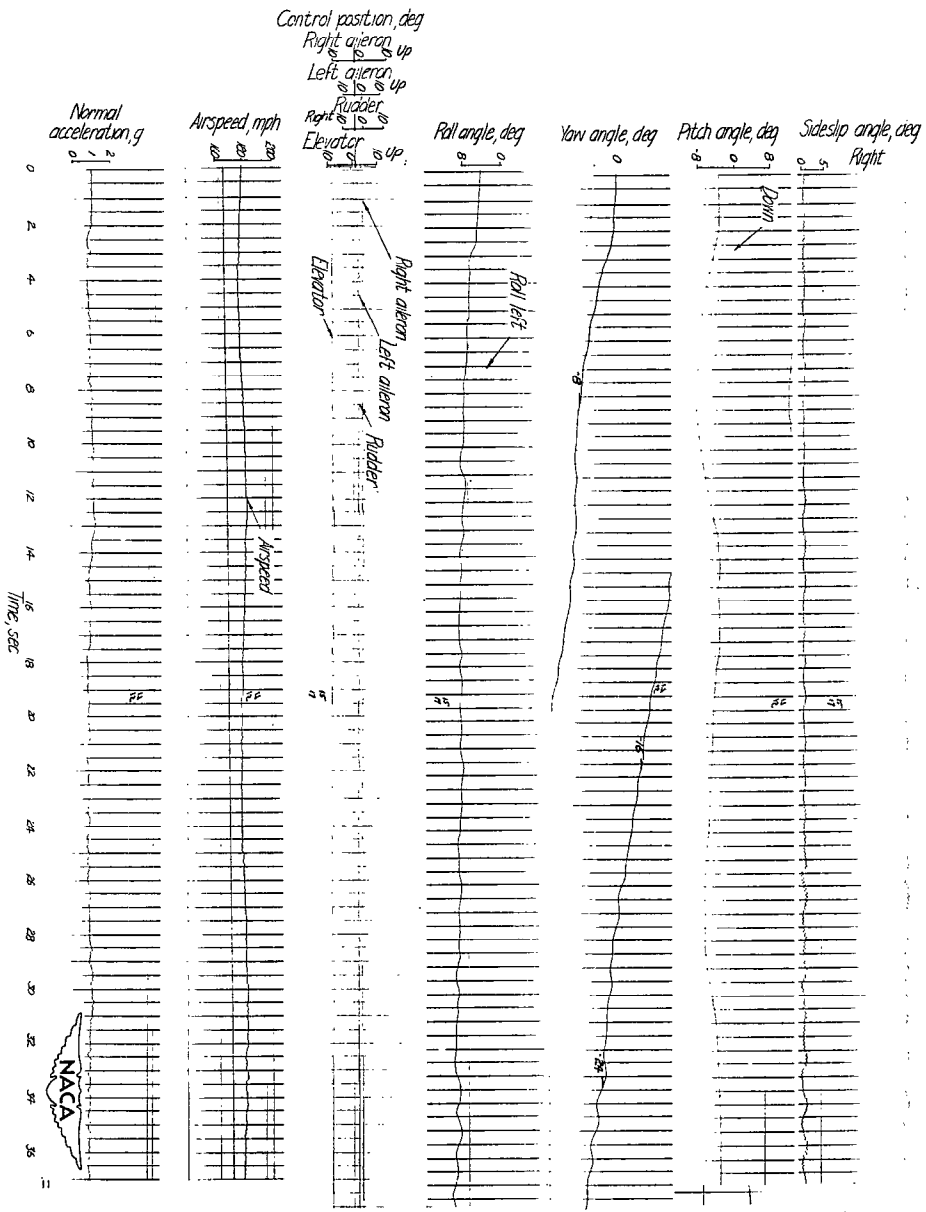
(a) Low speed.

Figure 21.- Time histories of the spiral divergence of the Beech B-35 Bonanza airplane. The records were started during straight and level flight at the time that the controls were released. The airspeed was controlled by moving the control wheel yoke.



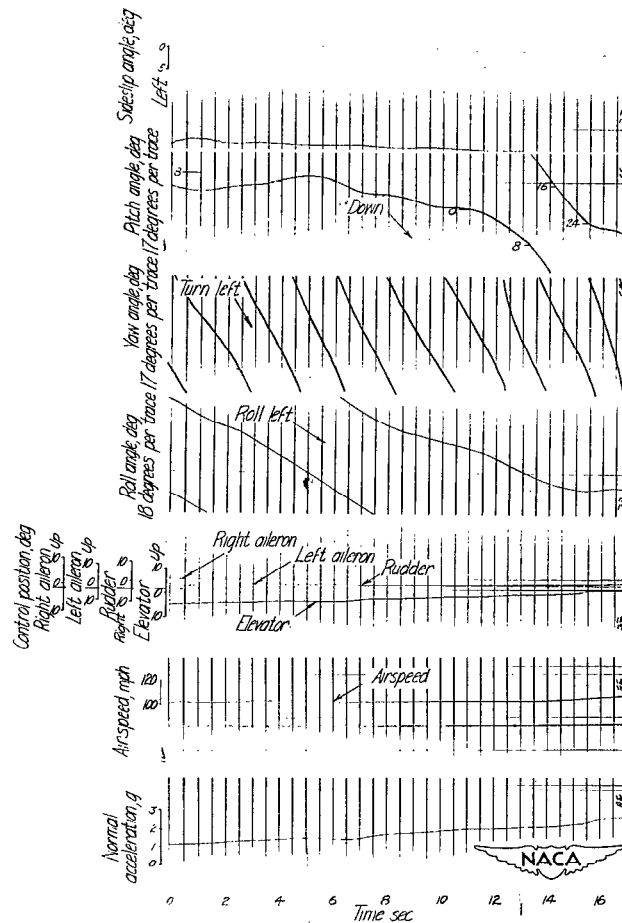
(b) Cruising speed.

Figure 21.- Continued.



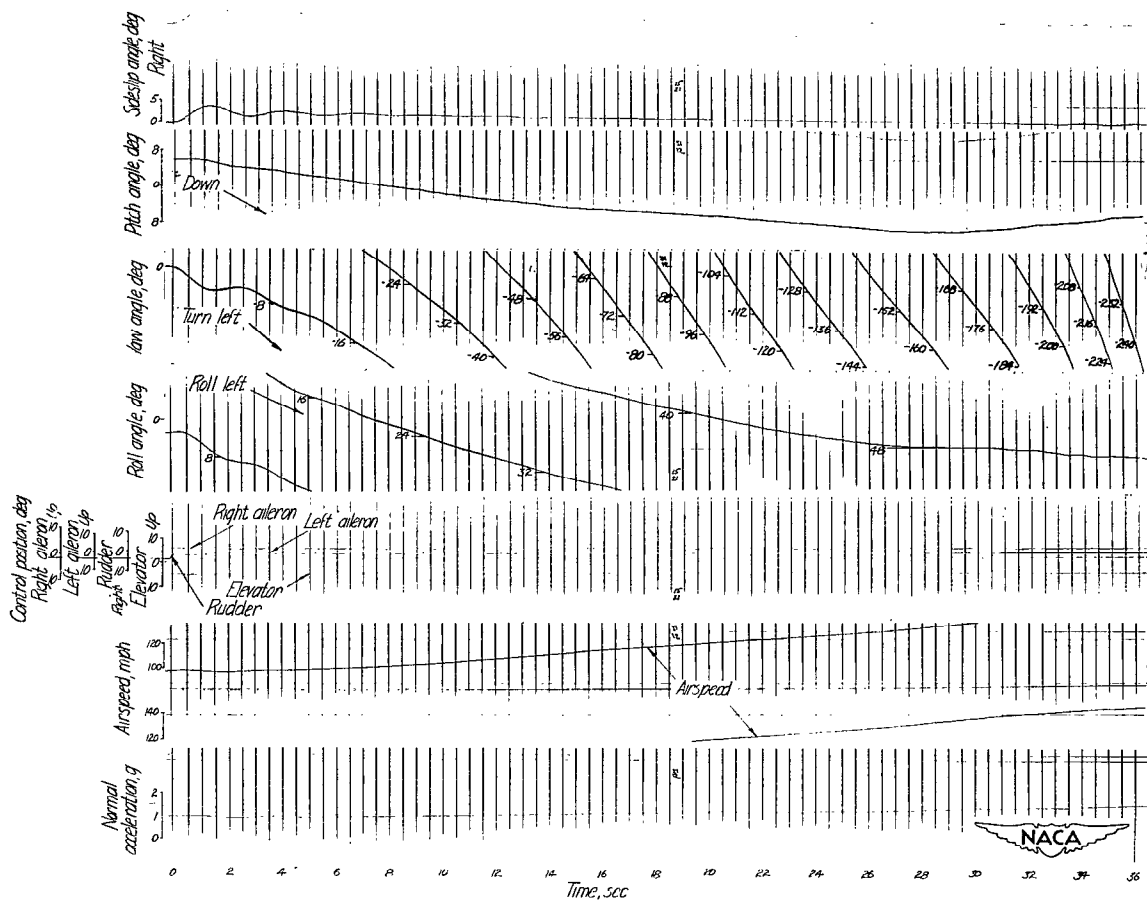
(c) High speed.

Figure 21.- Concluded.



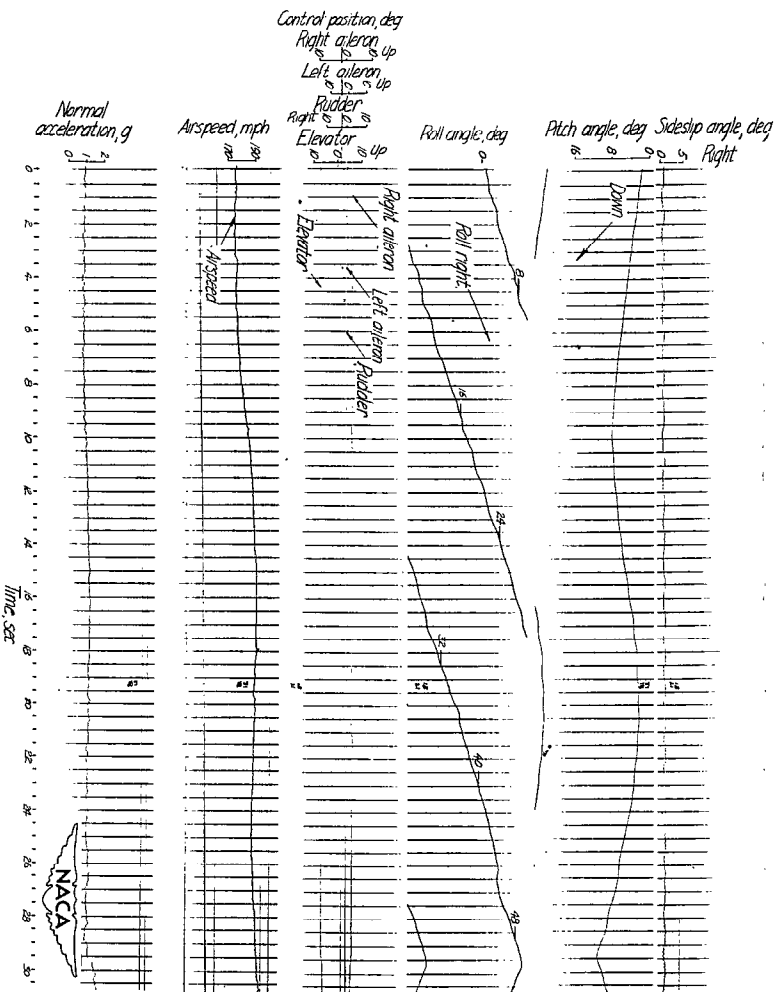
(a) Low speed. This maneuver was started at 72 miles per hour, but the record did not start until a speed of 102 miles per hour was reached.

Figure 22.- Time histories of the spiral divergence of the Beech B-35 Bonanza airplane. The records were started during straight and level flight at the time when all the controls were released. No attempt was made to control the airspeed.



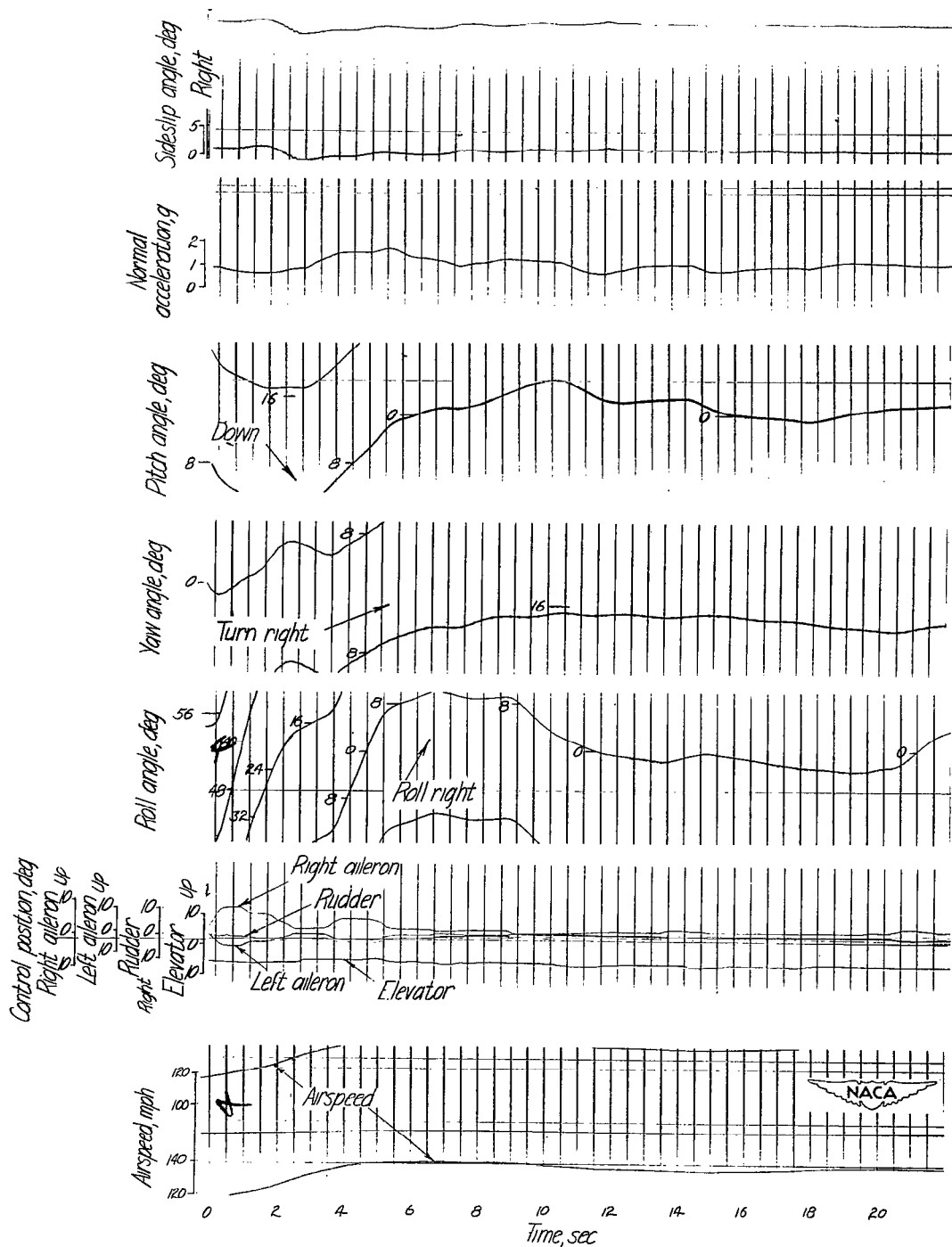
(b) Low speed.

Figure 22.- Continued.



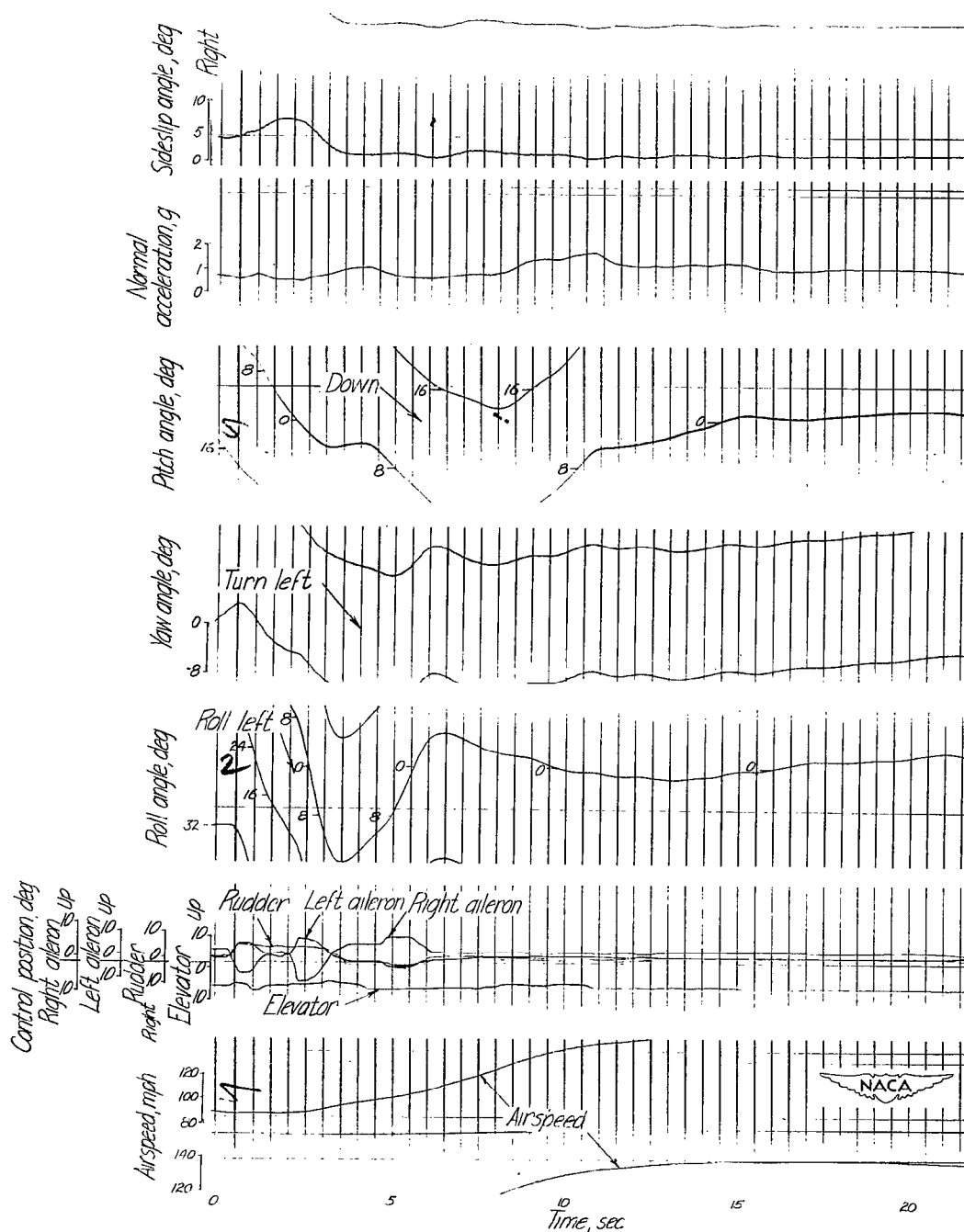
(c) High speed. Yaw angle not available.

Figure 22.- Concluded.



(a) Recovery from a left diving turn.

Figure 23.- Time histories of recoveries from large displacements while flying under a hood. Beech B-35 Bonanza airplane.



(b) Recovery from a climbing; right turn.

Figure 23.- Concluded.

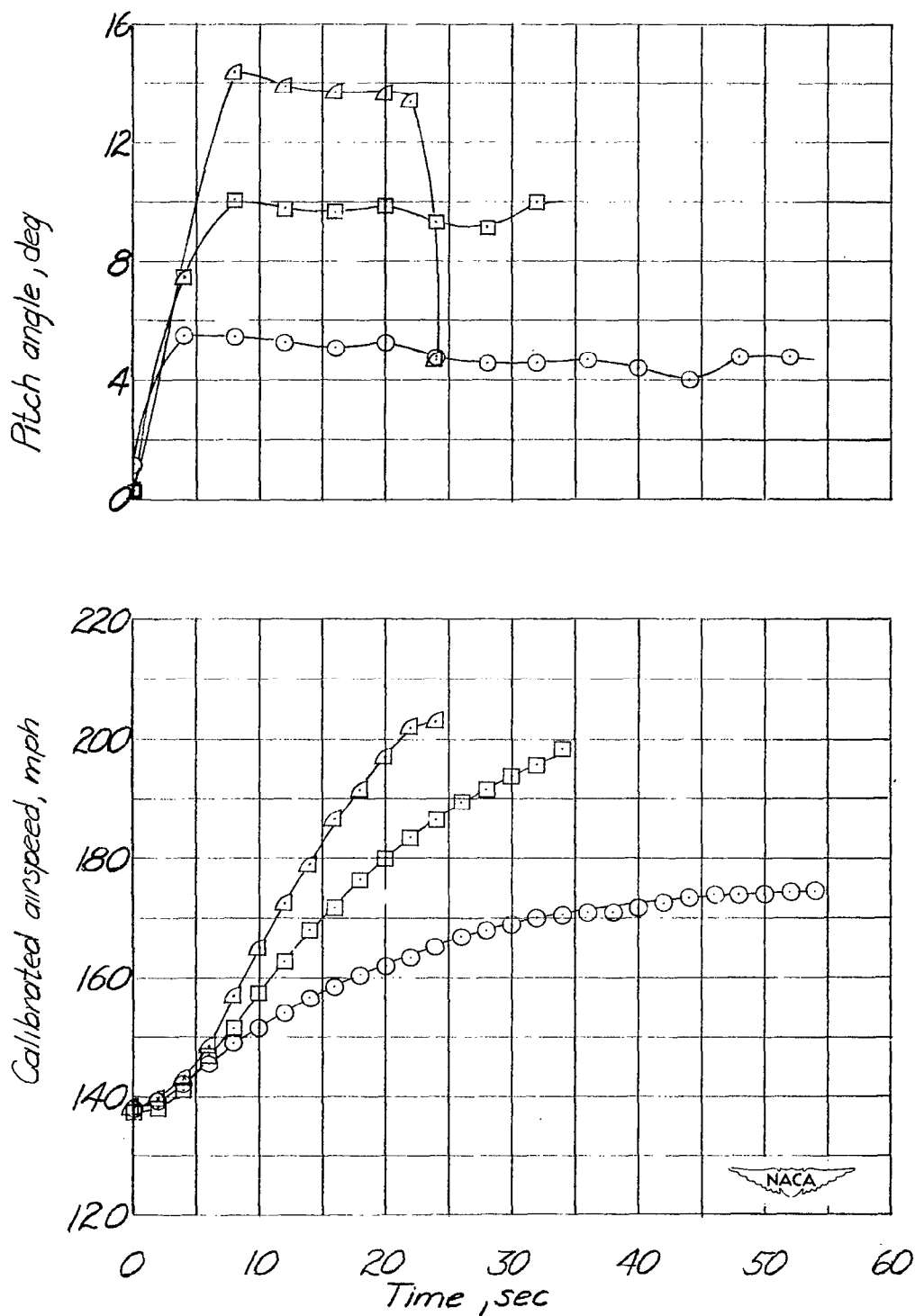


Figure 24.- Time histories of the airspeed in several shallow dives at constant power in the Beech B-35 Bonanza airplane.